



Digitized by the Internet Archive
in 2025

BULLETIN
OF
ENTOMOLOGICAL RESEARCH.

ISSUED BY THE IMPERIAL
INSTITUTE OF ENTOMOLOGY.

EDITOR : THE DIRECTOR.

VOL. 34.

LONDON :
THE IMPERIAL INSTITUTE OF ENTOMOLOGY,
41, QUEEN'S GATE, S.W.7.
1943.

IMPERIAL INSTITUTE OF ENTOMOLOGY.

Executive Council.

SHAMALDHARI LALL, C.I.E., Deputy High Commissioner, *Chairman*, India and Burma.

Sir DONALD FERGUSON, K.C.B., United Kingdom.

Lieutenant-Colonel J. G. ROBERTSON, Canada.

F. L. McDougall, C.M.G., Australia.

A. P. VAN DER POST, Union of South Africa.

A. L. POOLE (*acting*), New Zealand.

J. W. DULANTY, C.B., C.B.E., Eire.

D. JAMES DAVIES, C.B.E., Newfoundland.

W. C. ROBERTSON, Southern Rhodesia.

G. H. CREASY, C.M.G., O.B.E., Colonies, Protectorates and Mandated Territories.

Sir DAVID CHADWICK, K.C.M.G., C.S.I., C.I.E., *Secretary*.

Director and Editor.

Dr. S. A. NEAVE, C.M.G., O.B.E.

Head Office—British Museum (Natural History), Cromwell Road, London, S.W.7.

Publication Office and Library—41, Queen's Gate, London, S.W.7.

Director, Imperial Parasite Service.

Dr. W. R. THOMPSON, F.R.S.,

228, Dundas Street, Belleville, Ontario, Canada.

CONTENTS.

	PAGE
ANDREWARTHA, H. G.	
Diapause in the Eggs of <i>Austroicetes cruciata</i> , Sauss. (Acrididae) with particular Reference to the Influence of Temperature on the Elimination of Diapause... ..	1
BENSON, R. B.	
Studies in Siricidae, especially of Europe and southern Asia (Hymenoptera, Symphyta) (<i>illustrated</i>)	27
BUSVINE, J. R.	
The Toxicity of some common Fumigants to Body Lice (<i>illustrated</i>)	19
CALLAN, E. McC.	
Natural Enemies of the Cacao Thrips (<i>illustrated</i>)	313
CHINA, W. E.	
A new Genus and Species of Miridae (Bryocorinae) feeding on <i>Khaya grandifoliola</i> in the Gold Coast (Hemiptera Heteroptera) (<i>illustrated</i>)	287
COMPERE, H.	
A new and economically important Species of <i>Anagyrus</i> from Africa	129
HADDOW, A. J.	
Measurements of Temperature and Light in artificial Pools with Reference to the larval Habitat of <i>Anopheles (Myzomyia) gambiae</i> , Giles, and <i>A. (M.) funestus</i> , Giles (<i>illustrated</i>)	89
HINTON, H. E.	
The Larvae of the Lepidoptera associated with stored Products (<i>illustrated</i>)	163
HOWE, R. W.	
An Investigation of the Changes in a Bin of stored Wheat infested by Insects (<i>illustrated</i>)	145
JONES, M. G.	
A brown Aphis, <i>Aphis (Doralis) cognatella</i> , sp. n., found on Spindle Tree (<i>illustrated</i>)	213
KEVAN, D. K. McE.	
An Account of <i>Schistocerca flavofasciata</i> (De Geer 1773) in Trinidad (Orthoptera : Acrididae) (<i>illustrated</i>)	291
LE PELLEY, R. H.	
The Establishment of a new Species of <i>Anagyrus</i> in Kenya... ..	131
LEWIS, D. J.	
The Culicine Mosquitos of Eritrea (<i>illustrated</i>)	279

CONTENTS.

	PAGE
MACLEOD, J.	
A Survey of British Sheep Blowflies (<i>illustrated</i>)	65
MACLEOD, J.	
A Survey of British Sheep Blowflies. II. Relation of Strike to Host and edaphic Factors (<i>illustrated</i>)	95
MAMET, R.	
New Species of Coccoidea (Homoptera) from Mauritius (<i>illustrated</i>)	117
NIXON, G. E. J.	
A Synopsis of the African Species of <i>Meteorus</i> (Hym., Braconidae) (<i>illustrated</i>)	53
NIXON, G. E. J.	
A Synopsis of the Ethiopian and Indo-Malayan Species of <i>Micro- phanurus</i> (Serphoidea, Scelionidae) (<i>illustrated</i>)	135
NIXON, G. E. J.	
New Braconid Parasites of Australian wood-boring Beetles with Notes on the Subfamily Hecabolinae (Hym., Braconidae) (<i>illustrated</i>)	257
PARR, H. C. M.	
The Culicine Mosquitos of Syria and the Lebanon	245
POSNETTE, A. F.	
Resistance of <i>Theobroma cacao</i> to <i>Sahlbergella</i> spp. on the Gold Coast	159
POTTER, C. & TATTERSFIELD, F.	
Ovicidal Properties of certain Insecticides of Plant Origin. (Nicotine, Pyrethrins, Derris Products) (<i>illustrated</i>)	225
ROBINSON, G. G.	
The Use of a Plaster Substratum for testing Pyrethrum-oil Films against <i>Ornithodoros moubata</i> , Murray (Acarina: Argasidae) (<i>illustrated</i>)	269
SQUIRE, F. A.	
Phototropism in Insects—an Indictment of the Light- trap Method	113
STACKELBERG, A. A.	
A new Species of <i>Finlaya</i> , Theo. (Diptera, Culicidae) from Ussuri Land	311
VAN SOMEREN, G. R. C.	
Notes on the Mosquitos of British Somaliland	323
VOLKONSKY, M. T.	
Rearing Locusts in Captivity	253

BULLETIN

OF

ENTOMOLOGICAL RESEARCH.

VOL. 34.

1943.

DIAPAUSE IN THE EGGS OF *AUSTROICETES CRUCIATA*, SAUSS.
(ACRIDIDAE) WITH PARTICULAR REFERENCE TO THE INFLUENCE
OF TEMPERATURE ON THE ELIMINATION OF DIAPAUSE.

By H. G. ANDREWARTHA.

Waite Agricultural Research Institute, Adelaide.

A. Introduction.

In South Australia the grasshopper, *Austroicetes cruciata*, Sauss., occurs in a restricted climatic belt. In this area the summer is hot and dry; the growing period for annual vegetation lasts for about 4 to 6 months during the cooler part of the year. The grasshopper has one generation a year. The eggs are laid in the soil during November. They hatch during the following September, usually during the early part of the month (Andrewartha, 1940).

The embryo of *Austroicetes* enters a state of diapause a few days after the eggs are laid, while the embryo is still in the small "plate-like" stage -fig. 1 of Steele (1941). Eggs which were collected from the field in November (a few days after they were laid), in January, and in March were incubated at 25°C. and 30 C. on moist plaster of paris for nine months. None emerged, and all died eventually. In the field during the summer, the embryo does not completely cease developing, but development goes on so slowly that the embryo requires six months to reach the stage that *Melanoplus* reaches in 21 days at 25°C. (Slifer, 1932).

The elimination of diapause is associated with low temperature. In summer the temperatures are high, and consequently they have little influence on the elimination of diapause. In April, May and June, particularly at night, lower temperatures occur and the elimination of diapause proceeds more rapidly. In the field diapause eventually disappears about mid-June (Birch, 1942).

The term "diapause" was coined by Wheeler (1893) to specify that stage in the development of the embryo of *Conocephalus* at which the embryo ceased to move tail-first over the yolk and remained stationary for a period before beginning the final movements of blastokinesis. That part of blastokinesis which occurred after "the diapause" was called "katatrepsis" by Wheeler. During katatrepsis, the embryo first became backwardly flexed and then migrated over the yolk head first towards

the anterior pole of the egg. With Wheeler, diapause was purely an embryological term. Henneguy (1904) extended the meaning of the term to cover the state of "arrested development" which was known to occur in the eggs of *Bombyx* and the larvae of *Liparis*. Since then, the term has been used by different authors to refer to various degrees of inhibited development. These range from the simple inhibition due to cold to the complicated (and apparently obligate) "developmental block" which is found, for example, in the eggs of certain Acridids (Bodine, 1929; Slifer, 1932) and univoltine races of *Bombyx* (Umeya, 1926). The term has also been applied to those cases of apparently facultative arrested development which may occur in the larvae of *Loxostege* (Steinberg & Kamensky, 1936) and *Platyedra* (Squire, 1940), and in various stages of *Lucilia* (Cousin, 1932) when the environment is unfavourable for rapid growth.

It is logical to separate those cases of arrested development, due directly to the low temperature of the environment, from those in which development appears to be inhibited by some factors internal to the organism. In the former case, normal development will be resumed as soon as the organism is returned to an adequate temperature: in the latter case, development continues to be inhibited even though the organism is experiencing apparently favourable temperature and moisture. There is, however, little justification for separating the apparently facultative diapause found, for example, in *Loxostege* from the apparently obligate diapause which occurs in the eggs of *Melanoplus*. The work reported in this paper provides evidence that the latter phenomenon also may be related to the unsatisfactory nourishment of the organism.

This paper is concerned with laboratory experiments which show the influence of exposure to various temperatures upon the elimination of diapause in the eggs of *Austroicetes cruciata*.

B. Methods.

All the eggs were dug up in the field, mostly from Wilmington, South Australia, but some from Deniliquin, New South Wales. The eggs were always separated from the pods. They were incubated on moist plaster of paris. Birch (1942) showed that this method provides favourable conditions for the development of the eggs. Where necessary, the appropriate humidity was obtained with sulphuric acid solutions in desiccators. The temperature was controlled in incubators, some of which remained constant to $\pm 0.1^\circ\text{C}$. and others to $\pm 0.2^\circ\text{C}$. When it was necessary to examine the morphology of the embryo, the eggs were fixed either in Bouin's fixative at 70°C . or in Carnoy-Lebrun's fixative (containing mercuric chloride) at room temperature, stained with borax-carmin and examined in clove oil with a binocular microscope.

C. Experimental Results.

(1) Viability of Eggs in Diapause at different Temperatures and Humidities.

Eggs in diapause may remain alive for many months. For example, 600 eggs collected at Wilmington between 24th and 30th November, 1938, were kept in diapause for 180 days. Diapause was then eliminated by exposing the eggs to 13.5°C . for 90 days. They were then incubated at 25°C .: 79 per cent. emerged, showing that viability was still high despite 180 days in diapause (Table I).

Another lot of 1,000 eggs which were collected at the same time were divided into five lots and incubated for 270 days on moist plaster of paris at 13.5°C ., 20°C ., 30°C ., 35°C . and 40°C .. They were examined at intervals to determine the number still alive. In this case the appearance of the eggs was the criterion; they remained turgid and free from mould while they remained alive; dead eggs became flaccid and

usually were attacked by moulds. After 270 days at 13.5°C., all the eggs were still alive; at higher temperatures fewer eggs survived (Table II). No nymphs emerged from any of the eggs except from those kept at 20°C.; 8 nymphs (4 per cent.) emerged at this temperature.

TABLE I.

Showing the percentage Emergence from Eggs of Austroicetes cruciata which had remained in Diapause for 180 Days.

Preliminary treatment	Percent. emergence at 25°C.
35°C. for 60 days; 20°C. on moist plaster of paris 120 days; 13.5°C. for 90 days	79
40°C. and 5°C. on alternate days for 60 days; 20°C. on moist plaster 120 days; 13.5°C. 90 days	80
35°C. 30 days, 5°C. 30 days; 20°C. on moist plaster 120 days; 13.5°C. 90 days	78

TABLE II.

Showing the percentage Survival of Eggs in Diapause of A. cruciata after Incubation at various Temperatures for specified Periods.

Temperature	Duration exposure on moist plaster (in days)					
	30 days	60 days	90 days	120 days	180 days	270 days
13.5°C.	100	100	100	100	100	100
20°C.	100	100	100	100	100	82
30°C.	99	99	96	94	53	4
35°C.	98	98	94	92	43	3
40°C.	87	83	45	0	0	0

The eggs which were incubated on moist plaster of paris remained alive for a shorter period than eggs exposed to the same temperatures in air at 75 per cent. or 55 per cent. relative humidity (see Table III).

TABLE III.

Showing the Survival of Eggs in Diapause of A. cruciata exposed on moist Plaster of Paris and in Air at 75 per cent. and 55 per cent. R.H.

Duration of exposure (days)	Percentage of eggs still alive								
	30°C.			35°C.			40°C.		
	Moist	75% R.H.	55% R.H.	Moist	75% R.H.	55% R.H.	Moist	75% R.H.	55% R.H.
90	96	99	98	94	99	98	45	97	96
180	53	87	79	43	84	82	0	67	60
210	40	68	34	35	67	41	0	11	5

(2) *Some Treatments which were Inadequate to eliminate Diapause.*(a) *Desiccation at moderate temperatures.*

Eggs which were collected at Wilmington between 24th and 30th November, 1938, were incubated at 30°C. for 30 days and then desiccated as follows. Two hundred eggs at a time were exposed for 60, 90, 150 or 210 days at 30°C., 35°C. or 40°C., in air at 55 per cent. or 75 per cent. relative humidity. The eggs were subsequently incubated at 20°C. for four months. The emergence of nymphs varied from 0.5 per cent.; the average for all treatments was 2.2 per cent., compared with 4 per cent. in the controls which were incubated continuously at 20°C. for 11 months. Details of the survival rates of the eggs in the various treatments were given in an earlier paper (Birch & Andrewartha, 1942).

(b) *Exposure to low temperature when the embryo was not at a suitable stage of development.*

Diapause was not eliminated in eggs which were exposed to low temperature when the embryo was in stage 6 of Steele (1941). In this early stage of the embryonic development, segmentation of the embryo is still incomplete.

The eggs were collected from the field in November, and kept at 30°C. for 90 days before being placed at the appropriate low temperature. They were exposed for periods varying from 50 to 116 days to 11.5°C., 13.5°C. or 16.3°C.; they were subsequently incubated at 25°C. In Table IV the percentage emergence is given, also the percentage of embryos to complete katatrepsis, since the completion of katatrepsis in eggs which fail to hatch indicates that diapause has been partially eliminated.*

TABLE IV.

Showing Percentage of Eggs of A. cruciata which hatched, or completed Katatrepsis at 25°C. after a preliminary Exposure to low Temperature at Stage 6.

Temperature	50 days at low temp.		70 days at low temp.		90 days at low temp.		116 days at low temp.	
	emerged %	kat. complete %	emerged %	kat. complete %	emerged %	kat. complete %	emerged %	kat. complete %
11.5°C.	0	0	0	1	7	22	10	70
13.5°C.	0	2	0	4	0	4	0	6
16.3°C.	0	1	0	2	0	0	0	0

Similarly, diapause was not completely eliminated from eggs which were exposed to 13.5°C. for two separate periods: the first when the embryos were in the "small-plate" stage (Fig. 1 of Steele 1941), and the second when the embryos had grown bigger than the stage normally reached in nature by the end of anatrepsis. The eggs were collected at Wilmington during November, 1939. They were divided into four lots and exposed to 13.5°C. for 60, 75, 90 or 110 days. They were then incubated at 25°C. for 60 days. During this time none hatched and none completed katatrepsis. So they were then exposed to 13.5°C. for 80, 65, 50 or 30 days, bringing the total exposure at 13.5°C. to 140 days for every lot of eggs. They were then incubated again at 25°C. Details of the hatchings are given in Table V.

Diapause was not eliminated during the first exposure at 13.5°C. because the embryo was too small. Diapause was eliminated from less than half the eggs during

* For a discussion of the growth and development of embryos in the artificial environment of the experiment see below, p. 11 and Table XI.

the second exposure to 13.5°C., because most of the embryos had grown too big during the 60 days at 25°C. which followed the first exposure to 13.5°C. In general, the embryos were in the position normally occupied at the end of anatrepsis but they were bigger than normal embryos at the end of anatrepsis. The embryos were about half to two-thirds as long as the egg, though many showed evidence of length-wise compression. They were stouter than normal embryos; the body walls had grown up about half way around the yolk. The appendages were fore-shortened as in a normal embryo at the end of anatrepsis, but differentiation in the appendages had proceeded to a stage normally found after the dorsal closure of the embryo is complete.

The data in Table V show that the exposure to 13.5°C. for 140 days was more effective for eliminating diapause when the preliminary exposure was shorter and the second period longer. This was because abnormal growth had proceeded further with those embryos which had spent the longer time at 13.5°C. during the preliminary exposure to that temperature, and because once the embryo had grown bigger than the stage normally reached at the end of anatrepsis, abnormally long exposures to low temperature were required to eliminate diapause.

TABLE V.

Showing the percentage Emergence of Eggs of A. cruciata incubated at 25°C. after preliminary Periods at 13.5°C. and 25°C.

Days at 13.5°C.	...	...	...	60+80	75+65	90+50	110+30
Percentage emergence	...	...	...	47	37	21	5

(3) *The Influence of (a) low Temperature, (b) Duration of Exposure to low Temperature, and (c) The Stage of Development of the Embryo, on the Elimination of Diapause.*

It was clear from the above experiments that the influence of low temperature on the elimination of diapause is complicated because of different effects of temperature on the different stages of the embryo. Consequently the following factorial experiment was done to evaluate the influence of the above three factors and their interactions.

About 3,500 eggs were collected at Deniliquin, New South Wales. They were dissected from the pods and kept at 16°C. during the following three weeks. The experiment began on 22nd February. At this time most of the embryos had not yet completed segmentation of the body. Most were in the stage shown in Fig. 3, a few in the stage shown in Fig. 7 of Steele (1941). The eggs were divided into 67 lots. Each of the 67 treatments was done with four replicates. The number of eggs per replicate was not constant; 20 eggs were used for the treatments in which variability was expected to be least, 80 for those in which the variability was expected to be greater. The eggs were kept on moist plaster of paris throughout the experiment. They were kept in incubators which maintained the temperature constant to $\pm 0.1^\circ\text{C}$. The extent to which diapause had been eliminated by any treatment was measured by the number of nymphs which hatched when the eggs were incubated at 25°C.

Three variables were used: temperature level, the duration of exposure to low temperature and the stage of the embryo at the beginning of the exposure to low temperature. The details of the experimental plan are set out in Table VI. The eggs were first exposed on alternate days to 25°C. and the appropriate low temperature (6.5°C., 10°C. or 13.3°C.); this allowed the embryo to grow. After this treatment at alternating temperatures the eggs were exposed to the appropriate constant low temperature for the appropriate period. The details are best considered under three

heads: (1) With one-third of the eggs the total duration of exposure to low temperature was kept constant, and two periods at alternating temperatures were used. Thus, during the exposure to alternating temperatures the eggs were at the low temperature for either 20 or 63 days. They were then exposed to the constant low temperature to 80 days. (2) With one-half of the eggs the period at alternating temperature was continued until the eggs had reached one of three arbitrarily chosen stages of development. The eggs were then kept at the constant low temperature for 45 days irrespective of the duration of the period at alternating temperatures. The three stages of development which were chosen were:—(A) Eyespots were visible in the posterior fifth of the egg: they were just passing from the stage where they appear slit-like and are becoming crescent-shaped. The embryo was at about the stage normally reached at the end of katatrepsis, *i.e.* at stage 10 of Steele (1941). (B) The eyespots were visible in the middle half of the egg: their long axis was just ceasing to be transverse to the long axis of the egg.† (C) The eyespots were in the anterior

TABLE VI.

Showing Details of the experimental Layout.

Eggs collected in the field Jan. 20-30th, 1941, and kept at 16°C. for 3 weeks. Embryo at the stage where segmentation is nearly complete	(a)	{ Eggs exposed to 25°C. and 6.5°C. on alternate days	{	for 40 days (<i>i.e.</i> 20 days at 6.5°)	{	at 6.5°C. for 45 days***	All eggs incubated at 25°C.		
					{	at 10.0°C. for 45 days***			
					{	at 13.3°C. for 45 days***			
					{	at 6.5°C. for 60 days*			
					{	at 10.0°C. for 60 days*			
					{	at 13.3°C. for 60 days*			
						for 126 days (<i>i.e.</i> 63 days at 6.5°)		{	at 6.5°C. for 45 days***
					{	at 10.0°C. for 45 days***			
					{	at 13.3°C. for 45 days***			
					{	at 6.5°C. for 17 days*			
					{	at 10.0°C. for 17 days*			
					{	at 13.3°C. for 17 days*			
						until embryo reached Stage A		{	at 6.5°C. for 45 days**
					{	at 10.0°C. for 45 days**			
					{	at 13.3°C. for 45 days**			
		until embryo reached Stage B	{	at 6.5°C. for 45 days**					
	{	at 10.0°C. for 45 days**							
	{	at 13.3°C. for 45 days**							
		until embryo reached Stage C	{	at 6.5°C. for 45 days**					
	{	at 10.0°C. for 45 days**							
	{	at 13.3°C. for 45 days**							
	(b)	{ Eggs exposed to 25°C. and 10°C. on alternate days	{	Five groups with similar layout to above		{ Incubated at 25°C.			
	(c)	{ Exposed to 25°C. and 13.3°C. on alternate days	{	Five groups with similar layout to above		{ Incubated at 25°C.			

*Described as section "(1)" of the experiment (see Table VIII).

**Described as section "(2)" of the experiment (see Table X).

***Described as section "(3)" of the experiment.

† In most embryos the head-lobe region was backwardly flexed as if katatrepsis was just beginning. The embryos were slightly abnormal in that they were broader than normal embryos at this stage, and the differentiation of the appendages was somewhat more advanced than in normal embryos.

third of the egg.† (3) The remaining one-sixth of the eggs were exposed to the constant low temperature for 45 days after either 40 or 126 days at alternating temperature (*i.e.* either 20 or 63 days at low temperature during the period at alternating temperatures). Three low temperatures were used both for the exposure to alternating temperatures and for the exposure to constant low temperature. These were 6.5°C., 10.0°C. and 13.3°C. The plan of the experiment is summarised in Table VI. Only one branch of Table VI is fully expanded, namely the one in which the preliminary alternating temperatures were 25°C. and 6.5°C. When fully expanded the other two branches of the table, *i.e.* the ones in which the preliminary alternations were at 25°C. and 10°C. and at 25°C. and 13.3°C. are identical with this one.

Controls were incubated at 25°C. as follows: at the beginning of the experiment, after 20 and 63 days at low temperature, at the alternating temperatures and after

TABLE VII.

Showing percentage Emergence in Controls incubated at 25°C.

Preliminary treatment	Days incubated at 25°C.	Percentage emergence
No preliminary treatment. Incubated at 25°C. for 270 days ...	270	0
Exposed on alternate days to 25°C. and 6.5°C. for 253 days ...	—	56
Exposed on alternate days to 25°C. and 10.0°C. for 253 days ...	—	58
Exposed on alternate days to 25°C. and 13.3°C. for 253 days ...	—	31
Exposed on alternate days to 25°C. and 6.5°C. for 126 days ...	90	0
Exposed on alternate days to 25°C. and 10.0°C. for 126 days ...	90	5
Exposed on alternate days to 25°C. and 13.3°C. for 126 days ...	90	0
Exposed on alternate days to 25°C. and 6.5°C. for 40 days (embryo at stage "A") ...	90	0
Exposed on alternate days to 25°C. and 10.0°C. for 40 days (embryo at stage "A") ...	90	0
Exposed on alternate days to 25°C. and 13.3°C. for 40 days (embryo at stage "A") ...	90	0
Exposed on alternate days to 25°C. and 6.5°C. until embryo stage "B" (198 days) ...	30	80
Exposed on alternate days to 25°C. and 10.0°C. until embryo stage "B" (160 days) ...	30	83
Exposed on alternate days to 25°C. and 13.3°C. until embryo stage "B" (218 days) ...	30	88
Exposed on alternate days to 25°C. and 6.5°C. until embryo stage "C" (198 days) ...	30	95
Exposed on alternate days to 25°C. and 10.0°C. until embryo stage "C" (160 days) ...	30	93
Exposed on alternate days to 25°C. and 13.3°C. until embryo stage "C" (198 days) ...	30	93

† All the embryos had completed revolution and were facing the anterior pole of the egg. The same abnormalities as in stage "B" were present but somewhat more strongly developed.

the embryos had reached stages "A," "B" and "C." In addition, three controls were exposed on alternate days to 25°C. and 13.3°C., 25°C. and 10°C., or 25°C. and 6.5°C. from the beginning of the experiment. The numbers of nymphs to emerge from the various control lots are shown in Table VII.

For greater simplicity in analysing the results, the experiment has been divided into three parts.

(a) All the treatments in which the eggs were exposed to low temperature for an aggregate of 80 days have been brought together in Table VIII. These are the treatments marked with one asterisk in Table VI.

TABLE VIII.

Showing percentage Emergence from Eggs of A. cruciata exposed to low Temperature for an Aggregate of 80 Days.

		Low temp. employed during exposure to alternating temp.									Grand mean (for each constant low temp.)
		6.5°C.			10.0°C.			13.3°C.			
Days at low temp. during alternations		20 days	63 days	Mean	20 days	63 days	Mean	20 days	63 days	Mean	
Days at constant low temp.		60 days	17 days		60 days	17 days		60 days	17 days		
Low temp. used for exposure to constant low temp.	6.5°C.	30	10	20	70	55	63	30	23	27	36
	10.0°C.	95	45	70	100	23	62	90	15	53	61
	13.3°C.	15	20	18	65	30	48	8	15	12	25
Mean		47	25	36	78	36	57	43	18	31	

Significant Differences in Percentage P=0.01.

Between constant temperature	...	...	...	...	...	...	...	12.1%
Between alternating temperature	...	...	...	...	...	...	...	12.1%
Between duration at all alternating temperatures	...	...	...	...	...	...	...	9.9%
Between duration at one alternating temperature	...	...	...	...	...	...	...	17.1%
Between individual treatments	...	...	...	...	...	...	...	29.5%

All three variables, *i.e.* the temperature during the exposure to constant low temperature, the temperature during exposure to alternating temperatures, and the duration of exposure at alternating temperatures, influenced the percentage emergence significantly at the 1 per cent. level of probability. The interaction of "constant temperature" on "alternating temperature" was significant at the 1 per cent. level; likewise the interaction of "duration at alternating temperature" on "constant temperature" was significant at the 1 per cent. level; but the interaction of "alternating temperature" on "duration at alternating temperature" was not significant. This means that the influence of temperature during the exposure to constant low temperature depended upon the low temperature experienced during the preliminary exposure to alternating temperatures. Similarly, the influence of temperature during the exposure to a constant low temperature depended upon the duration of the period at alternating temperatures,* but the influence of low temperature during the preliminary exposure to alternating temperatures was not affected by the duration of the period at alternating temperatures.

* These interactions are related to the influence of low temperature on the growth of the embryo (see below p. 11 *et seq.*).

In addition to the interactions between the variables, the influence of each variable on per cent. emergence may be considered. As regards exposure to constant low temperature, the percentage emergence after exposure to 10°C. was significantly greater (at the 1 per cent. level) than that at both 6.5°C. and 13.3°C. The percentage emergence at 6.5°C. was significantly greater (at 5 per cent. level) than that at 13.3°C.

Considering alternating temperatures, again the percentage emergence at 10°C. was significantly greater (at 1 per cent. level) than that at either of the other temperatures.

Considering the duration of exposure to low temperature during the period at alternating temperature, the percentage emergence for those lots exposed for 20 days was significantly higher (at 1 per cent. level) than for the ones exposed for 63 days. This is true for each temperature taken alone and for all the temperatures taken together. This is explained by the abnormal growth of the embryo during the exposure to alternating temperature. The influence of low temperature for eliminating diapause is most effective when the embryo is at the stage normally reached at the end of anatrepsis. The more that the influence of low temperature is directed towards allowing the embryo to grow beyond this stage (this happens during prolonged exposure to alternating temperatures), the greater the aggregate exposure to low temperature needed finally to eliminate diapause. This point is demonstrated again in Table IX—compare the emergences of 26 per cent. and 74 per cent. for eggs which had been at the constant low temperatures for 17 and 45 days respectively after 63 days at the low temperatures during the exposure to alternating temperature. The development of the embryos under the artificial conditions of the experiment are discussed below, p. 11.

TABLE IX.

Showing the percentage Emergence at 25°C. for Eggs which had been exposed to 6.5°C., 10.0°C. or 13.3°C. for 0, 17, 45 or 60 days following a preliminary Treatment at alternating Temperatures.

Details of preliminary exposure to low temp. during treatment at alternating temp.		0 days at const. low temp.	17 days at constant low temp.				45 days at constant low temp.				60 days at constant low temp.			
			6.5°	10.0°	13.3°	Mean	6.5°	10.0°	13.3°	Mean	6.5°	10.0°	13.3°	Mean
20 days at low temp. during preliminary treatment	6.5°	0	—	—	—	—	0	—	—	—	30	95	15	47
	10.0°	0	—	—	—	—	0	35	5	13	70	100	65	78
	13.3°	0	—	—	—	—	5	48	0	18	30	90	8	43
	Mean	0	—	—	—	—	2	41	3	14	43	95	29	56
63 days at low temp. during preliminary treatment	6.5°	0	10	45	20	25	80	93	95	89	—	—	—	—
	10.0°	5	55	23	30	36	78	40	25	48	—	—	—	—
	13.3°	9	23	15	15	18	88	90	80	86	—	—	—	—
	Mean	2	29	28	22	26	82	74	67	74	—	—	—	—

Significant Differences. P=0.01.

Between individual treatments	26.9%
Between groups of 3 treatments (e.g., between durations at one constant temperature; or between constant temperature at one duration) ...	15.5%
Between groups of 9 treatments (e.g., between durations at all temperatures)	8.9%

Considering individual treatments, the greatest emergence occurred when the eggs were exposed to 10°C. for 60 days after the shorter period at alternating temperatures. These three treatments did not differ significantly from one another; all three were significantly better (at the 1 per cent. level) than all the others except two, namely the ones having 60 days at 6.5°C. or 10°C. following 20 days at 10°C. during the period at alternating temperatures. The two next best treatments were those having 60 days at 6.5°C. or 13.3°C. following 20 days at 10°C. during the period at alternating temperature. These were significantly better (at 5 per cent. level) than all the remaining treatments.

(b) All the treatments in which the eggs experienced 17, 45 or 60 days at a constant low temperature after either 20 or 63 days at low temperature during a preliminary period at alternating temperatures have been brought together in Table IX. During this preliminary period the eggs were exposed on alternate days to 25°C. and 13.3°C., 10.0°C. or 6.5°C., for 40 or 126 days. Some of the data in Table IX are already shown in Table VIII, but they have been re-arranged in Table IX to bring out some further points. Table IX includes all the treatments marked with either one or three asterisks in Table VI.

The influence of the duration of the exposure to constant low temperature was significant (at 1 per cent. level) whether the eggs had been exposed to the preliminary treatment at alternating temperatures for the short or the longer period.

When the eggs were exposed to the preliminary treatment at alternating temperatures for 40 days, the percentage emergence from the eggs which had been exposed to 10°C. (either during the alternations or as a constant temperature) was significantly greater than from all the other lots of eggs which had been exposed to 6.5°C. or 13.3°C.

When the eggs were exposed to the preliminary treatment at alternating temperatures for 126 days, the temperature subsequently experienced during the exposure to constant low temperature had no significant influence on the percentage emergence. Further, with those eggs which had the longer exposure to constant low temperature (45 days), the percentage emergence from the eggs which experienced 10°C. during the period at alternating temperature was significantly less than that from the other two lots of eggs at 6.5°C. and 13.3°C. This means that 10°C. favoured the growth of the embryo during the period at alternating temperature more than the other two temperatures; the consequent abnormal development of these embryos reduced the effectiveness of the subsequent exposure to constant low temperature.

(c) All the treatments in which the eggs were exposed to low temperature for 45 days after having been allowed to reach a particular stage of development (*i.e.* all the treatments marked with two asterisks in Table VI) are brought together in Table X. In this table the emphasis is on the stage of the embryo, not on the period at low temperature during the preliminary treatment at alternating temperature. For example, after eggs had been exposed to 25°C. and 6.5°C. on alternate days for 198 days (*i.e.* they had experienced 6.5°C. for 89 days) some of them were at stage B and others at stage C. During the preliminary treatment the eggs were exposed on alternate days to 25°C. and 6.5°C., 10.0°C. or 13.3°C. until they reached the required stage of development (see above page 7 for description of the stage of development). They were then placed at a constant low temperature, 6.5°C., 10.0°C. or 13.3°C. for 45 days; they were then incubated at 25°C. Controls were incubated at 25°C. from the time that the treatment lots were placed at the constant low temperature.

There was a big and significant difference between the percentage emergence between stages A and B. A smaller but still significant difference in the percentage emergence occurred between stages B and C. Parallel differences occurred in the controls. With stage A, the percentage emergence after 45 days at low temperature was small but it was significantly greater than in the controls. With stages

TABLE X.

Showing the percentage Emergence for Eggs of *A. cruciata*. Eggs in which the Embryos were at three different Stages of Development were exposed to 6.5°C., 10.0°C. or 13.3°C. constantly for 45 days.

Stage of embryo at end of preliminary treatment at alternating temperature	Details of preliminary treatment at alternating temperature	Low temp. used during 45 days at constant low temperature				Control 0 days at const. low temp.
		6.5°	10.0°	13.3°	Mean	
A	20 days at 6.5°C.	0	—*	—*	—*	0
	20 days at 10.0°C.	0	35.0	5.0	13.3	0
	20 days at 13.3°C.	5.0	47.5	0	17.5	0
	Mean	1.7	41.3	2.5	13.2	0
B	89 days at 6.5°C.	97.5	92.5	95.0	95.0	80.0
	80 days at 10.0°C.	62.5	95.0	82.5	80.0	82.5
	109 days at 13.3°C.	—*	—*	—*	—*	87.5
	Mean	80.0	93.8	88.8	87.5	83.3
C	89 days at 6.5°C.	97.5	100.0	95.0	97.5	95.0
	82 days at 10.0°C.	95.0	90.0	95.0	93.3	92.5
	99 days at 13.3°C.	92.5	95.0	92.5	93.2	92.5
	Mean	95.0	95.0	94.2	94.7	93.2

* No results available for these treatments.

Significant Differences. $P=0.01$.

Between individual treatments	17.7%
Between individual control and the mean for the three corresponding treatments	14.5%
Between groups of 3 treatments	10.3%
Between mean for control Stage A and mean for all treatments Stage A	8.7%
Between mean for control Stage B and mean for all treatments Stage B ...	8.9%
Between mean for control Stage C and mean for all treatments Stage C ...	8.4%
Between means for all treatments Stages A and B	7.0%
Between means for all treatments Stages B and C	6.6%

B and C, the exposure to low temperature for 45 days did not increase the percentage emergence over that found for the controls. Temperature did not influence the percentage emergence significantly, neither when it was experienced as part of the preliminary exposure to alternating temperatures nor as a constant temperature. This is explained by the high rate of emergence from eggs in which katatrepsis had begun before the eggs were incubated. Apparently the high rate of emergence masked the influence of temperature. The superiority of 10°C. is indicated by the emergences from those eggs in which the embryos had reached stage "A".

(4) Morphological Development of the Embryo.

In the Acrididae the embryo completes the first third to half of its development with its anterior end still directed towards the posterior pole of the egg. When the development has been completed the head of the embryo is close to the anterior pole of the egg. The movements of the embryo which result in its re-orientation in the egg were defined by Wheeler (1893) as katatrepsis. Katatrepsis has been described for *Conocephalus* by Wheeler (1893), for *Melanoplus* by Slifer (1932) and for *Austroicetes cruciata* by Steele (1941). In Table XI the stages of development reached by the embryos in the different experiments are described with reference to the stages of normal embryos figured by Steele (1941).

In normal embryos just prior to katatrepsis the anterior fifth of the egg is filled by a clear fluid (amniotic fluid). In the absence of this fluid katatrepsis did not take place. Katatrepsis did not always occur even when the amniotic fluid was present in adequate amounts. The compressed appearance of some embryos which failed to undertake katatrepsis indicated that the yolk had offered effective resistance to the movement of the embryo backwards over the surface of the yolk. Longitudinal compression of the embryo, to a more or less degree, was always associated with the presence of an abnormal amount of amniotic fluid (Table XI).

TABLE XI.

*Showing Stage of Development reached by Embryos after specified Treatments.**

Stage of embryo at beginning	Treatment	Stage of embryo after treatment		For percentage emergence see Table
		Position of embryo in egg	Morphological stage of embryo	
Fig. 1	35°C. for 90 days	Figs. A-C	Figs. 2-3	—
Fig. 1	30°C. for 90 days	Fig. F	Figs. 7-9. Practically no amniotic fluid	—
Fig. 1	20°C. for 90 days	Figs. G-K	Figs. 8-10. Embryo about normal, no evidence of compression lengthwise	—
Fig. 1	20°C. for 270 days	Figs. K-14	Figs. 10-15. Appendages backward in relation to size of embryo and its position in the egg	—
Fig. 1	5°C. for 90 days	Figs. A-C	Figs. 2-3	—
Fig. 1	13.5°C. for 116 days	Figs. K-L but amniotic fluid occupies anterior $\frac{1}{4}$ of egg	Figs. 8-9. Embryo showing signs of compression lengthwise	IV
Figs. 3-5	13.5°C. for 200 days	Figs. 12-15	Figs. 10-15. In general the embryos were small relative to the position they occupied in the egg, <i>i.e.</i> blastokinesis had progressed abnormally with respect to growth. Where katatrepsis was still at an early stage, there was an abnormal amount of amniotic fluid present	—
Figs. 3-7	11.5°C. for 90 days	Figs. F-H but amniotic fluid occupies anterior $\frac{1}{4}$ of egg	Stages 8-9. Embryo compressed and distorted as if from pressure from front. Tail region coiled back on itself. Abnormal amount of amniotic fluid present	IV
Fig. 1	13.5°C. for 90 days 25°C. for 60 days	Fig. K but amniotic fluid occupies anterior $\frac{1}{4}$ of egg	Fig. 10. Embryo broader than normal, body walls about half-way round the yolk. Appendages still short as in Fig. 14 but differentiated as in Figs. 15-16	V

* The stage of development of the embryo is specified with reference to the stages figured by Steele (1941).

TABLE XI—continued.

*Showing Stage of Development reached by Embryos after specified Treatments**

Stage of embryo at beginning	Treatment	Stage of embryo after treatment		For percentage emergence see Table
		Position of embryo in egg	Morphological stage of embryo	
Figs. 3-5	6.5°C. and 25°C. on alternate days for 126 days	Fig. K but amniotic fluid fills anterior $\frac{1}{4}$ of egg	Fig. 10 but embryo broader. Embryo compressed lengthwise—some strongly so. Appendages short as in Fig. 10 but differentiated more like Fig. 15	VII and VIII
Figs. 3-5	10°C. and 25°C. on alternate days for 126 days	Fig. K, figs. 11-13, but amniotic fluid occupies anterior $\frac{1}{2}$ of egg	Figs. 10-13 but embryos strongly compressed lengthwise. The appendages short as in Fig. 10 but differentiated as in Fig. 15. A great excess of amniotic fluid present	VII and VIII
Figs. 3-5	13.3°C. and 25°C. on alternate days for 126 days	Fig. K but amniotic fluid occupies anterior $\frac{1}{4}$ of egg	Fig. 10 but embryo broader and compressed lengthwise. Appendages short as in Fig. 10 but differentiated as in Figs. 15-16	VII and VIII
Figs. 3-5	Stage "A" of Table X	Fig. K	Fig. 10. Embryo nearly normal, only slightly too broad in proportion to length	X
Figs. 3-5	Stage "B" of Table X	Figs. 11-12	Figs. 11-12 but differentiation of the appendages is more like Figs. 13-14	X
Figs. 3-5	Stage "C" of Table X	Fig. 13	Fig. 13 but embryo somewhat shorter. Size of appendages as in Fig. 14 but differentiation of appendages more like Fig. 16	X

*The stage of development of the embryo is specified with reference to the stages figured by Steele (1941).

With eggs which were exposed to a constant temperature within the range 16–25°C. the embryo grew slowly and amniotic fluid accumulated either normally or in abnormal amounts: but katasitropis did not occur, apparently because the yolk was in an unsuitable condition to permit the passage of the embryo over the surface of the yolk. Exposure to constant temperature in the range 30–35°C. inhibited almost completely both the growth of the embryo and the production of amniotic fluid. When eggs were exposed to a constant temperature in the range 11–13°C., the embryos grew slowly and the amniotic fluid was accumulated in abnormal amounts. At 13.3°C. the embryos ultimately (after about 200 days) completed katasitropis while growth was still sub-normal relative to the stage of blastokinesis (Table XI). When eggs were exposed on alternate days to 25°C. and a low temperature (6.5°C., 10.0°C. or 13.3°C.) the embryos grew and amniotic fluid accumulated in about normal quantities. With prolonged exposures (more than 40 days) the embryo grew beyond the stage at which katasitropis normally begins, without undertaking katasitropis. Ultimately about half the embryos did complete katasitropis and emerge (Table VII).

D. Discussion.

(1) *The Elimination of Diapause.*

The embryo of *Austroicetes cruciata* enters a state of diapause a few days after it is laid. At this stage prolonged exposure to low temperature did not eliminate diapause (Table IV). On the other hand, exposure to high temperatures (30°-40° C.) inhibited development almost completely (Table XI). Prolonged exposure (of the order of 100-150 days) to moderate temperatures (16°-25° C.) enabled the embryo to grow to a stage at which adequate exposure to suitable low temperature eliminated diapause (Table I). Intermittent exposure to low and high temperature enabled the embryo to reach a similar stage of development; this stage was reached after 40 days when the eggs were exposed on alternate days at 25° C. and 10° C. (Table VIII). Probably a shorter period would have sufficed if relatively more time had been spent at the lower temperature.

Diapause was eliminated from the eggs of *A. cruciata* by exposing the eggs to suitable low temperatures for adequate periods when the embryo was at a suitable stage of development. If the exposure to low temperature was inadequate or inadequately timed with reference to the stage of development of the embryo, diapause was not eliminated. Instead the influence of the exposure to low temperature was reflected in abnormal growth by the embryo when it was returned to a higher temperature. Thus the influence of the exposure to "low" temperature on the elimination of diapause was complicated by its influence on the growth of the embryo. With embryos which had made abnormal growth, a longer exposure to low temperature was needed to eliminate diapause (Tables V, VIII and IX); in some cases this abnormal growth prevented the embryo from undertaking the final movements of blastokinesis, *i.e.* katatrepsis (Table IV).

Katatrepsis is a critical stage in the development of the embryo. With eggs developing normally in the field, diapause is finally eliminated about the time that katatrepsis is completed (Birch, 1942). In the laboratory 16-93 per cent. of the embryos which completed katatrepsis hatched depending on the conditions (Tables IV and X). In only three cases out of the several thousands of eggs examined did a nymph hatch from an egg in which the embryo had failed to complete katatrepsis. At temperatures which were too low for the embryo to hatch, katatrepsis still continued. When eggs were kept at a constant temperature of 13.5°C., most of the embryos had completed katatrepsis after 200 days (Table XI). At 13.5°C. embryos completed their development and the white cuticle was digested (as at higher temperatures) but the nymph did not hatch (Birch, 1942). Embryos which had completed their development at 13.5°C. hatched in a few hours when they are placed at 25°C.; this suggests that failure to hatch at 13.5°C. is due to the torpor of the embryo at this temperature. Birch also reported that slight progress was made with katatrepsis when eggs were kept at 8°C.

The appearance of many of the embryos which had experienced the artificial conditions of these experiments, considered together with the data from the experiments, suggested that exposure to low temperature operated in three ways to enable katatrepsis to occur: (a) by modifying the yolk in such a way that the embryo was able to move over the surface of the yolk. The distortion and compression of the embryos listed in Table XI always was of such a nature as to suggest that the posterior end of the embryo had been pushed against an unyielding substance by some pressure from in front. (b) By enabling the embryo to grow when it was returned to a favourable high temperature. Unless the exposure to low temperature was adequately timed with reference to the stage of the embryo, the growth which occurred when the egg was returned to a favourable high temperature was abnormal. (c) By favouring the accumulation of amniotic fluid which, by exerting pressure on the expanded head lobe regions, actually initiated the backward flexing of the embryo

which marks the beginning of katatrepsis. Generally the greatest amounts of amniotic fluid were present in those eggs which had been longest at low temperature. Also the greatest compression and distortion of the embryo usually was associated with the greater amounts of amniotic fluid.

I am not aware that any other author has suggested this function for the amniotic fluid. Slifer (1932 *a*) described convulsive pulsating movements of the embryo of *Melanoplus* during katatrepsis. Such movements may help the migration of the embryo over the surface of the yolk during the latter part of katatrepsis, but it is hardly likely that they are responsible for the initial backward flexing of the embryo. Nor is it likely that these pulsations are important at such temperatures as 13.5°C. or 8°C., since at 13.5°C. the nymph is too sluggish to burst the chorion and emerge; but amniotic fluid is secreted freely at these temperatures.

(2) *The Nature of Diapause.*

The occurrence of diapause in insects has been attributed alternately to the presence of an "inhibiting factor" and the absence of a "growth factor" (Bodine, 1932; Baumberger, 1917; Wigglesworth, 1933). Although Bodine and his co-workers have made an intensive study of the physiology and biochemistry of the eggs of *Melanoplus differentialis*, no substance has yet been demonstrated to be causally connected with diapause.

With *A. cruciata* the cessation of growth during diapause and the subsequent development after exposure to low temperature may be associated with the nutrition of the embryo, the exposure to low temperature simply making the food reserves in the yolk available to the embryo. The processes associated with this modification of the yolk proceed at temperatures at least as low as 6°C.; they are most rapid at about 10°C.; they fall off rapidly after about 13.3°C., but they are still going on slowly at 25°C. The processes associated with the growth of the embryo reach their maximum speed about 30°C.; at 13.5°C. they are slow but can still be measured; at 8°C. no measurable growth occurs (Birch, 1942). A slight amount of growth was observed (but not measured) at 11.5°C. (Table XI).

With *A. cruciata* the ranges of temperature at which these two processes are active overlap only slightly. Consequently diapause is well developed in this species. Similarly, the eggs of *Dociostaurus* and *Circotettix* fail to develop when they are exposed continually to "favourable" high temperatures but develop normally after an exposure to low temperature (Carothers, 1923; Uvarov, 1928). With certain other Acridids the eggs when placed at a favourable high temperature develop continuously until they hatch. All locusts, e.g., *Chortoicetes terminifera* (Swan, unpublished), *Locusta* and *Schistocerca* (Hamilton, 1936), and those grasshoppers which normally hibernate as adults or nymphs, e.g., *Chortophaga* (Bodine, 1929), belong to this group. With this type of egg it may be that the favourable range of temperature for yolk "conditioning" is much the same as for the growth of the embryo. The occurrence of intermediates like *Melanoplus* are explained naturally on this hypothesis since with them the overlapping of the temperature ranges for the two sets of processes may occur to an extent intermediate between those found in *Austroicetes* and *Chortoicetes*.

With *M. differentialis* two types of eggs are produced: in a small proportion of the eggs diapause does not occur. With the majority of the eggs diapause occurs after about 21 days at 25°C. Such eggs will ultimately complete their development if they are left at temperatures of 25–35°C., but a preliminary exposure to low temperature (0–10°C.) will result in an increased rate of development when the eggs are returned to 25°C. (Burdick, 1937). The eggs of *M. mexicanus* respond to temperature in much the same way except that they appear to be more variable (Parker, 1930).

This explanation of diapause, based on the nourishment of the embryo, brings the obligate diapause found in the eggs of certain *Aceridids* into line with the facultative "diapause" found in various stages of many other species, *i.e.* the eggs of *Bombyx*, the larvae and pupae of *Lucilia*, and the larvae of *Loxostege* and *Platyedra*.

With *Bombyx* the occurrence of diapause in the eggs is determined by some influence from the somatic cells of the mother. Thus if ovaries from one race are transplanted into another race during the larval stage they show diapause characteristic of the new host. With some strains of *Bombyx* the extent to which diapause occurs in the eggs depends upon the temperature at which the mother was reared. Even the temperature at which the eggs were reared is important; eggs incubated at 25°C. gave rise to females which laid more "diapause" eggs than did eggs which were incubated at 15°C. (Umeya, 1926). With *Loxostege* the larvae entered a state of arrested development if they were reared on unfavourable food. Temperature was less important but, in general, the proportion of larvae entering diapause was greatest when they were reared on food or at temperatures which tended to retard the rate of growth (Steinberg & Kamensky, 1936). Similarly, with *Platyedra* the proportion of larvae which entered diapause depended upon the oil and water contents of their food, being greatest when the water content was low and the oil content high (Squire, 1940). With *Lucilia* unfavourable conditions of food, temperature or humidity which tended to reduce the rate of growth also tended to increase the proportion of larvae or pupae which entered diapause (Cousin, 1932).

E. Summary.

Diapause should not be confused with simple inhibition of growth due to cold.

The embryo of the grasshopper, *Austroicetes cruciata*, enters a state of diapause a few days after the egg is laid. The diapause is obligate like that found in the eggs of *Circiolettix*, rather than facultative like that found in the larvae of *Platyedra*. These types of diapause should be regarded as two extremes of the one phenomenon rather than two distinct phenomena.

Diapause was eliminated when the egg was exposed to adequate low temperature for an adequate period when the embryo was at a suitable stage of development. If the period at low temperature was inadequate, or if the embryo was not at a suitable stage of development when the exposure to low temperature occurred, diapause was only partially eliminated. In such cases, the exposure to low temperature resulted in an abnormal growth by the embryo when the egg was returned to a favourable high temperature, but development was not completed.

The influence of low temperature on the elimination of diapause was due chiefly to changes which occurred in the yolk during exposure to low temperature. Thus yolk which had been modified in this way became suitable for the nourishment of the embryo, and it no longer obstructed katatrepsis. This explanation of the nature of the obligate diapause in the eggs of *Austroicetes* brings this phenomenon into line with the facultative diapause in the larvae of *Platyedra*, which has been shown to be associated with the nourishment of the larva.

Diapause was eliminated most rapidly at temperatures between 6°C. and 13°C. The embryo grew most rapidly at about 30°C.; below 13°C. growth practically ceased. The absence of overlapping of the temperature ranges for these two processes may explain the presence of diapause in *Austroicetes*. The occurrence of a less pronounced diapause in the eggs of *Melanoplus* may be due to a partial overlapping of the temperature range for the two processes. Similarly the absence of diapause in the eggs of *Locusta* may be explained on the assumption that in this species the two processes proceed over the same temperature range.

References.

- ANDREWARTHA, H. G. (1940). J. Dep. Agric. S. Aust., **43**, p. 99.
- BAÜMBERGER, J. R. (1917). Ann. ent. Soc. Amer., **10**, p. 179.
- BIRCH, L. C. (1942). Aust. J. exp. Biol. med. Sci., **20**, p. 17.
- & ANDREWARTHA, H. G. (1942). Aust. J. exp. Biol. med. Sci., **20**, p. 1.
- BODINE, J. H. (1929). Physiol. Zool., **2**, p. 459.
- (1932). Physiol. Zool., **5**, p. 549.
- BURDICK, H. C. (1937). Physiol. Zool., **10**, p. 156.
- CAROTHERS, E. E. (1923). Trans. Amer. ent. Soc., **49**, p. 7.
- COUSIN, G. (1932). Bull. Biol., Suppl., **15**, p. 341.
- HAMILTON, A. G. (1936). Trans. R. ent. Soc. Lond., **85**, p. 1.
- HENNEGUY, L. F. (1904). Les Insectes, p. 424.
- PARKER, J. R. (1930). Bull. Mont. agric. Exp. Sta., no. 223.
- SLIFER, E. H. (1932). J. Morph., **53**, p. 1.
- (1932 a). Biol. Zbl., **52**, p. 223.
- SQUIRE, F. A. (1940). Bull. ent. Res., **30**, p. 475.
- STEELE, H. V. (1941). Trans. roy. Soc. S. Aust., **65**, p. 329.*
- STEINBERG, D. M. & KAMENSKY, S. A. (1936). Bull. Biol., **70**, p. 145.
- UMEYA, Y. (1926). Bull. sericult. Exp. Sta. Chosen, no. 1. (Quoted from Wigglesworth: "Principles of Insect Physiology, p. 9.)
- UVAROV, B. P. (1928). Locusts and Grasshoppers, p. 229.
- WHEELER, W. M. (1893). J. Morph., **8**, p. 141.
- WIGGLESWORTH, V. B. (1933). Quart. J. micr. Sci., **76**, p. 269.

* The Transactions of the Royal Society of South Australia have not been distributed to overseas subscribers during the war. Reprints of this paper are available at the Waite Research Institute, Adelaide.

THE TOXICITY OF SOME COMMON FUMIGANTS TO BODY LICE.

By J. R. BUSVINE, Ph.D., B.Sc.

Entomological Department, London School of Hygiene and Tropical Medicine.

Introduction.

Outbreaks of typhus or other diseases associated with body lice must be considered as a possible result of prolonged and widespread warfare. The soundest way of checking these diseases is by eliminating the lice, and there would be scope for several types of delousing measures. For example, two of the fumigants dealt with in this paper (hydrogen cyanide and sulphur dioxide) are not now considered satisfactory for fumigating infested clothes, if other methods are available. (The cyanide is too dangerous to be used in this way, and the sulphur dioxide is likely to damage the fabrics.) On the other hand both these gases could be used to fumigate houses contaminated by a case of typhus if their toxicity to lice could be established. But although both fumigants have been used against lice in outbreaks associated with the last war, there is little or no critical experimental work published on their toxicity and efficiency.

The bed-bug, on the other hand, has received much attention in recent years, both on a laboratory and a practical scale. Accordingly bed-bugs were included in many experiments in this paper in the hope that the comparison might be useful.

Laboratory Experiments.

Treatment of Insects.

The lice were taken from a stock reared in gauze-bottomed pill-boxes kept against the skin of the leg during the day as described by Buxton (1939).

Fifteen to thirty minutes before an experiment, lice or eggs were removed, placed in small muslin bags and kept at the fumigation temperature which was 20°C. After the exposure, they were aired for an hour at the same temperature. Then the lice were put back into breeding boxes, examined daily and the mortality estimated 3 days after fumigation. The eggs were incubated at 30°C. and 60 per cent. R.H. to determine the percentage hatch.

The bed-bugs were reared in muslin-topped glass tubes at 20°C. and allowed to feed weekly on the ears of a lop-eared rabbit. They were kept at the same temperature after fumigation, and the mortality estimated 7 to 10 days after exposure. The longer interval was necessary because they did not either die or recover so rapidly as the lice on the leg (approximately 30°C.).

Fumigation Methods.

Experiments with hydrogen cyanide, sulphur dioxide and trichlorethylene were done in 5-litre glass flasks kept in a constant-temperature chest at 20°C. Liquid hydrogen cyanide was introduced with a micro-pipette and the concentration estimated by a gas sample drawn in each test.

The sulphur dioxide was delivered from a gas burette and samples were taken frequently to check the accuracy of delivery.

The trichlorethylene was added by a pipette, the quantities being sufficiently large for reasonably accurate dosage in this way.

Exposures to saturated vapours of naphthalene, paradichlorobenzene, etc., were simply made by lowering dishes or bags of insects into bottles containing excess of the substances under test.

TABLE I.
Statistics of Log Concentration/Probit kill Regression Lines.

Fumigant	Exposure (hours)	Insect	Stage	Average number used per test	Regression equation	Degrees of freedom	χ^2	P
Hydrogen cyanide	1	<i>Pediculus</i>	Adults	13.7	$y = 3.1329x + 0.8592$	7	6.5358	* > .05
"	"	"	III Nymphs	13.7	$y = 3.7886x - 0.5651$	4	1.6384	* > .05
"	"	"	Eggs	81.0	$y = 4.2339x - 0.3871$	3	1.4974	* > .05
"	2	"	Adult	17.7	$y = 3.6740x + 0.9665$	7	4.6318	* > .05
"	"	"	III Nymphs	14.9	$y = 2.9471x + 1.4567$	9	4.3861	* > .05
"	1	<i>Cimex</i>	Adults	14.9	$y = 2.4373x + 2.5987$	8	6.1597	* > .05
"	"	"	Eggs	45.0	Insufficient points	—	—	—
"	2	"	Adults	20.0	$y = 3.7328x + 3.2736$	5	1.1331	* > .05
Sulphur dioxide	1	<i>Pediculus</i>	Adults and III Nymphs	23.2	$y = 4.1158x + 1.2481$	8	14.5684	* > .05
"	"	"	Eggs	58.3	$y = 7.7665x - 5.6601$	6	44.5374	* > .05
"	"	<i>Cimex</i>	Adults	21.2	$y = 4.8969x + 1.1702$	3	2.3359	* > .05
"	"	"	Eggs	21.5	Insufficient points	—	—	—
Trichlorethylene	5	<i>Pediculus</i>	Adults and III Nymphs	39.0	$y = 8.1078x - 8.8042$	4	5.4342	* > .05
"	"	"	Eggs	62.5	$y = 11.3811x - 16.2372$	2	23.3768	* > .05
"	"	<i>Cimex</i>	Adults	45.3	$y = 10.5441x - 14.2792$	2	0.6917	* > .05
"	"	"	Eggs	35.0	$y = 5.7237x - 6.0017$	3	4.2544	* > .05

Results.

The critical doses of the fumigants were calculated by the methods described by Bliss (1935). Table I gives the regression line formulae and certain other statistics.

The relative toxicity of three fumigants to different stages of louse and bug is shown by the 50 per cent. and 99 per cent. lethal concentrations set out in Table 2. With respect to these three fumigants, the susceptibility of lice is rather similar to that of bed-bugs. The egg stage of both insects is more resistant to sulphur dioxide and trichlorethylene and less resistant to hydrogen cyanide than the other stages. The last nymphal stage of lice is slightly more resistant than the adult (which is often the case with the bed-bug). But the difference, although significant, is small and the two stages were pooled for experiments with sulphur dioxide and trichlorethylene.

TABLE II.

Lethal Concentrations in Milligrams per Litre of Fumigants for different Stages of Louse and Bug.

Fumigant	Exposure		Lethal concentrations to					
			<i>Pediculus</i>			<i>Cimex</i>		
			Egg	Nymph III	Adult	Egg	Adult	
Hydrogen cyanide ...	1 hour	50% kill	1.87	2.9	2.1	0.4	0.97	
" " ...	" "	99% "	6.6	12.1	11.6	1.2	8.7	
" " ...	2 hours	50% "	—	1.6	1.2	—	0.29	
" " ...	" "	99% "	—	9.8	5.4	—	1.2	
Sulphur dioxide ...	1 hour	50% "	23.6	8.1		13	6.8	
" " ...	" "	99% "	47	30		40	21.8	
Trichlorethylene ...	5 hours	50% "	73	50		84	67	
" " ...	" "	99% "	118	98		212	112	

In Table III will be found the lethal exposures for lice and eggs to substances tested as saturated vapours. The eggs were more resistant than nymphs and adults to all of them.

It will be seen that the less volatile compounds require longer exposures but that their effect is achieved by proportionally very much lower concentrations in air. This conforms to the general rule that equitoxic concentrations decrease on ascending various homologous series but the volatility decreases even faster; so the saturation concentrations of compound of lower molecular weight are generally most effective.

The practical importance of these facts is that non-volatile substances must be slow in action (unless they have some very unusual specific toxicity). Their advantage over more volatile fumigants is merely in economy; so little is used in producing a saturated atmosphere.

The crude samples of naphthalene are clearly more toxic than the refined chemical owing to the presence of phenols, cresols, etc., which add to the toxicity. The higher toxicity of impure naphthalene was noted by Nuttall (1918), who advised the use of "unwhizzed" (*i.e.* not purified by centrifuging) naphthalene.

TABLE III.

Lethal Exposures, in Hours, to saturated Vapours at 20°C.

		Lethal exposures to				Saturation concentration (20°C.)
		Eggs		Nymph III & Adults		
		50%	99%	50%	99%	
Drained creosote salts*	...	—	—	1½ hours	3 hours	—
Whizzed naphthalene...	...	—	—	1½ "	4 "	—
Pure flake naphthalene	...	24 hours	50 hours	4 "	12 "	0.6 mg./litre
Paradichlorbenzene	...	15 "	28 "	1 "	3 "	4.9 " "
Heavy naphtha	...	2 "	4 "	¾ "	1½ "	15 " "
Trichlorethylene	...	1 "	2½ "	⅓ "	½ "	410 " "

* "Drained creosote salts" are the crude source of naphthalene which can be partly purified of liquid impurities by centrifuging to "whizzed naphthalene." Further purification evolves the perfectly dry "flake naphthalene."

Field Trials.

House Fumigation.

It is well known that, in fumigating houses to eradicate bugs, the dose used in practice must be many times the concentration lethal in laboratory tests. This is to allow for leakage and absorption and to ensure a high concentration in the free space so that a lethal concentration may penetrate the crevices where the bugs hide.

Lice do not, properly speaking, infest a room; but large numbers of them may be found in a room inhabited by a very lousy person. In a bedroom in which an infirm and heavily infested man had been living, the writer once found countless numbers on the bedding and several thousands upon each of two small woollen mats on the polished floor. There were also some upon the curtains but few elsewhere in the room. This is to be expected from the known habits of the body louse which clings to the fibres of clothing or fabric. This habit makes it extremely easy to pick up stray lice on the clothing when entering heavily infested premises. If a man has to disinfect a room previously occupied by a lousy typhus patient, he is exposed to considerable risk both of acquiring infected lice and from inhaling louse faeces carrying *Rickettsia*. The danger from lice would be eliminated if the room were effectively fumigated.

A number of practical fumigations were conducted to ascertain the effectiveness of sulphur dioxide and hydrogen cyanide in killing lice under various conditions. Louse adults and eggs, and sometimes bugs as well, were confined in small muslin bags and about a half dozen of these were placed about the rooms before fumigation. The penetrating powers of the fumigants were tested by covering the bags with 1 to 6 layers of ordinary grey blanket* or by secreting them among furniture.

The buildings were sealed in the usual manner by strips of gummed paper over the cracks in doors, windows or ventilators. In most trials a long thin glass tube was left running from the centre of a room to the exterior so that gas samples could be drawn at intervals during the exposure. After exposure, the bags of insects were collected and aired. The lice were then put into breeding boxes and their eggs and the bugs were put into appropriate incubators.

* As used in A.R.P. posts, etc.

TABLE IV.
Summary of practical Fumigation Tests.

Fumigant	Trial No.	Site	Dose of gas—oz. per 1,000 cu. ft.	Weather		Concentration found (mgms./litre)						Kill of insects		
				Air temperature (midday)	Wind	1 hr.	2 hrs.	4 hrs.	6 hrs.	12 hrs.	24 hrs.	Exposed 0-1 layers of blanket	Inter-mediate 2-3 layers of blanket	Pro- tected 3-6 layers of blanket
Sulphur dioxide	2	I	96	12	4 C.	Slight	35	—	—	18	—	a.e.b.	a.e.b.	—
"	6	I	48	12	3 C.	Slight	—	18	—	7-6	—	—	a.e.	a.
"	11	II	96	12	10 C.	Moderate	26	31	24	18	6-6	a.e.	a.e.	a.e.
"	14	II	64	12	20 C.	None	16	27	24	18	—	a.e.	a.e.	a.e.
"	12	II	64	12	17 C.	Fairly strong	13	21	7-5	2-2	0-3	a.e.	a.e.	A.E.
"	13	II	32	12	25 C.	None	6	10	9	8	—	a.	a.	a.
"	15	II	32	12	20 C.	Strong	5	8-6	3-2	0-6	—	a.f.	a.f.	A.E.
Hydrogen cyanide	1	I	16	6	4 C.	Slight	9-8	9-7	—	3-5	—	a.e.b.	a.e.b.	—
"	5	I	16	5	3 C.	Slight	6-6	6-6	—	4-3	—	a.e.	—	a.e.
"	9	III	6	6	4 C.	Moderate	—	—	—	—	—	a.	a.	A.
"	4	IV	13	2	25 C.	—	—	—	—	—	—	a.e.b.	a.e.b.	a.e.b.
Chlorpierin	8	I	21	5	3 C.	Slight	—	—	—	—	—	a.e.B.	—	a.e.B.

Key to kills—

- A Adult lice survived
 a Adult lice all killed.
 B Louse eggs survived.
 b Louse eggs all killed.
 B Bug adults survived.
 b Bug adults all killed.

Sites

- I Flats.
 II Top room.
 III Ship.
 IV Fumigation van.

The fumigations were done on various dates between January and August so that a variety of weather conditions was included.

Description of Sites fumigated.

(I) The use of an unoccupied block of three-roomed flats was obtained through the kindness of Dr. Fenton, M.O.H., Kensington. I also had the valuable cooperation of Mr. Walters, Chief Sanitary Inspector of the Borough, in the trials in this building, which were very kindly carried out for me by Messrs. Associated Fumigators, Ltd.

These small self-contained flats which amounted to about 3,000 cubic feet each contained beds and blankets and a few articles of furniture. There were no carpets or curtains.

(II) A room of about 1,500 cu. ft. on the top floor of the London School of Hygiene and Tropical Medicine was used for a number of the tests. This room has two windows and a skylight (the latter being far from gas tight). It was empty except for some stacks of wooden laths.

(III) On one occasion bags of lice were put at various points aboard a destroyer just before a cyanide fumigation for cockroaches.

(IV) Bags of lice and bugs were secreted among some furniture about to be fumigated for bugs in a heated steel van used for the purpose by the Borough of Kensington Health Department.

Results.

The results of relevant experiments are summarised in Table IV.

The curves of concentration of sulphur dioxide during the course of some of the trials have been plotted in fig. 1. It will be seen that the maximum concentration was attained about two hours after the sulphur candles had been lighted. The fall in concentration after that was dependent to a remarkable degree upon the strength of the wind.

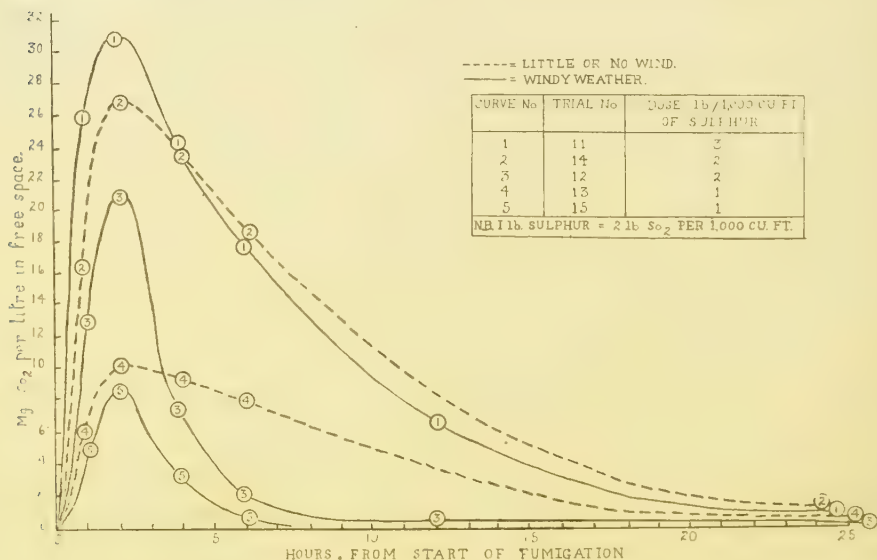


Fig. 1. Concentration curves of sulphur dioxide in fumigation trials (Site II).

Apart from revival of well protected lice after fumigations on windy days, sulphur dioxide proved quite effective. That the eggs revived in positions more exposed than the adults is not surprising in view of their greater resistance.

Although lice were found to be more resistant than bugs in the laboratory tests, the dose normally used to kill bugs in practice was sufficient to kill the lice too. The rather low dose used against cockroaches in the ship fumigation gave a fairly good kill of lice. The only revivals were in well protected places (in a closed drawer, in a suitcase, etc.).

The dosage in the single trial of chlorpicrin was based on recent Russian work with chlorpicrin as a delousing agent. Although it killed both lice and eggs, it does not appear suitable for house fumigation at this dosage, which was expensive and difficult to remove by airing. It will be noticed that bugs were not killed by this gas.

Bin Fumigation.

A very simple method of killing lice on garments is to put them into a dust-bin or a chest with a fumigant of low volatility such as naphthalene. Such substances

TABLE V.
Results of Bin Tests for disinfesting Garments.

Exposure	Test No.	Average temperature	Fumigant	Dose per bin	% kill of test insects	
					Lice	Eggs
20 hours	1	20°C.	Flake naphthalene... ..	Excess	24	50
" "	2	"	" " " " " "	"	17	—
" "	8	"	Whizzed naphthalene ...	"	73	—
" "	8	"	Drained creosote salts ...	"	100	—
" "	1	"	Paradichlorbenzene ...	"	100	50
" "	2	"	" " " " " "	"	81	—
" "	3	"	Heavy naphtha	32 cc.	100	70
" "	4	"	" " " " " "	16 cc.	100	64
" "	3	"	Trichlorethylene	32 cc.	100	100
" "	4	"	" " " " " "	16 cc.	100	96
5½ "	9	16°C.	Whizzed naphtha	Excess	14	—
" "	9	"	Drained creosote salts ...	"	36	—
" "	5	15°C.	Heavy naphtha	32 cc.	100	36
" "	6	17°C.	" " " " " "	16 cc.	100	25
" "	7	14°C.	" " " " " "	"	100	78
" "	5	15°C.	Trichlorethylene	32 cc.	100	100
" "	6	17°C.	" " " " " "	16 cc.	100	75
" "	7	14°C.	" " " " " "	"	96	90

- NOTE (i) In test 1, naturally infested clothes were used: in other tests, overalls with bags of lice in pockets.
(ii) 32 cc. per bin corresponds to 2 gallons per 1,000 cubic feet; or ½ cc. per litre.

require a long exposure and are useless as general delousing methods in which the clothes must be rapidly returned to their owners. On the other hand, the clothes of people going into hospital or the protective clothing of individuals working among lousy people can be left in a bin overnight without disadvantage.

A number of tests were made with an ordinary dustbin without any special means of sealing on the lid. Garments, either naturally or artificially infested with lice, were placed inside and sprinkled with the fumigant under test, which was also scattered on the bottom of the bin. After the exposure, samples of lice were removed and put into breeding boxes for subsequent examination as usual. The results are summarised in Table V.

In these practical tests the substances show the same order of efficacy as in the laboratory experiments. The results indicate the unreliability of solid fumigants for destroying lice and their ineffectiveness against the eggs.

Complete kills of adult lice were obtained in $5\frac{1}{2}$ hours by heavy naphtha and trichlorethylene at suitable doses. Eggs were only killed by the higher dose of trichlorethylene.

It is likely that neither of these liquids are ideal fumigants for lice on garments, but they are evidently more reliable than the solid fumigants mentioned.

Summary.

An outbreak of body lice might require several control measures according to circumstances. Two types of fumigant action have been investigated in the laboratory and the field :—

(1) House fumigation for disinfecting typhus-contaminated premises.

Lice were fairly similar to bed-bugs in their resistance to the fumigants tested. In practice, 16 oz./1,000 cubic feet of hydrogen cyanide will kill lice and eggs : 2 lb. of sulphur/1,000 cubic feet is also successful if the wind is not strong.

(2) Bin fumigation of garments by saturated vapours.

The saturated vapours of solids such as naphthalene and paradichlorbenzene are extremely slow in action ; even with 20 hours exposure at 20°C. they are unreliable. Liquids such as heavy naphtha or trichlorethylene are much more promising.

For reading and criticising this paper I am grateful to Professor Buxton in whose department the work was done. My thanks are also due to the Medical Research Council for a grant.

References.

- BLISS, C. I. (1935). The calculation of the dosage mortality curve.—*Ann. appl. Biol.*, **22**, p. 134.
BUXTON, P. A. (1939). *The Louse*.—London, E. Arnold & Co.
NUTTALL, G. H. F. (1918). Combating lousiness among soldiers and civilians.—*Parasitology*, **10**, p. 411.
-

STUDIES IN SIRICIDAE, ESPECIALLY OF EUROPE AND SOUTHERN ASIA (HYMENOPTERA, SYMPHYTA).

By ROBERT B. BENSON, M.A., F.R.E.S.,
Department of Entomology, British Museum (Nat. Hist.).

CONTENTS.

Introduction :	PAGE
(a) General	27
(b) The Length of the Ovipositor as a taxonomic Character	28
(c) The Genera	32
(d) The Species	32
Key to the Genera of the World	33
<i>Sirex</i> , L., with a Key to the Females of the Species occurring in Europe	35
<i>Xeris</i> , Costa	38
<i>Urocerus</i> , Geoffroy, with a Key to the Females of the Species occurring in Europe	38
<i>Tremex</i> , Jurine, with a Key to the Males and Females occurring in Europe	41
<i>Eriotremex</i> , gen. nov., with a Key to its Females	42
British Siricidae	44
(a) Recorded British Species	44
(b) Is there a native Siricid Element in Britain ?	44
(c) Is there a native British Form of <i>Urocerus</i> ?	45
(d) Is the dark Form of <i>Sirex juvencus</i> native in Britain ?	46
The Siricidae were not derived from the Jurassic Pseudosiricidae	46
Himalayan and Oriental Siricidae	47
Summary	49
References	49

INTRODUCTION.

(a) General.

As living larvae of SIRICIDAE have been introduced from time to time in timber, it was more than ever necessary, when drawing up keys to the British species, to study also the forms occurring in other parts of the world, especially continental Europe and North America, whence so much timber has been brought to Britain.

Unfortunately, as with most Hymenoptera, the collections of these insects in the British Museum are entirely inadequate for such a study. With this in mind, a revision of the world species was contemplated, with the help, it was hoped, of workers in other countries.

The British Museum collection was, some time ago, enriched by representatives of certain North American species received in exchange from Dr. J. C. Bradley (Cornell), and the material already in the collection was critically examined and named by the

same authority. More recently representatives of several species from Asia were received in exchange from Dr. V. V. Gussakovskii (Leningrad), after he had completed the part of his monograph dealing with the Palaearctic SIRICIDAE. Further exchanges and also loans were being arranged with various foreign museums now sadly cut off from us; nevertheless, it seems advisable to collect together these preliminary studies, especially in so far as they concern the European and British species. They include a key to the genera of the world and keys to the females of all the known species occurring in Europe.

Besides Dr. J. C. Bradley and Dr. V. V. Gussakovskii, whom I have already mentioned, I am also indebted to Dr. A. C. Stephen, for the loan of Scotch SIRICIDAE from the Royal Scottish Museum, and to Prof. G. D. Hale Carpenter, D.M., M.B.E., for lending me the types of *Tremex insignis*, Smith, and *T. insularis*, Smith, and giving me access to other SIRICIDAE in the Hope Department, Oxford.

(b) The Length of the Ovipositor as a Taxonomic Character.

Previous workers (Konow 1905, Bradley 1913, Waterston 1928, Gussakovskii 1935, Conde 1935 and Takeuchi 1938), in studying these insects, have compared the length of the ovipositor, or parts of the ovipositor, with the length of the abdomen in characterising species; I have found this gives very unsatisfactory results as the abdomen frequently becomes telescoped in drying, and I have, therefore, sought for some more reliable standard for comparison. This I have found by comparing the total length of the ovipositor sheath (measured from the base of the oblong plate or second valvifer) with the length of a forewing (measured from the apex of a tegula). This character I shall refer to as the ovipositor/forewing ratio. The point in the venation to which the ovipositor sheath would reach if stretched along the fore margin of the forewing from the tegula serves as a rough guide in separating the different forms of *Urocerus* (fig. 2).

It is not being suggested that the length of the forewing is a standard measure of the size of an insect; in fact it is not unlikely that some races of these insects have longer wings in proportion to their size than other races. Where the ovipositor is very short compared with the forewing, the apical portion of the ovipositor sheath (referred to hereafter as the sawsheath) compared to the whole ovipositor sheath (sawsheath plus oblong plate) may give a more decisive result (see fig. 1).

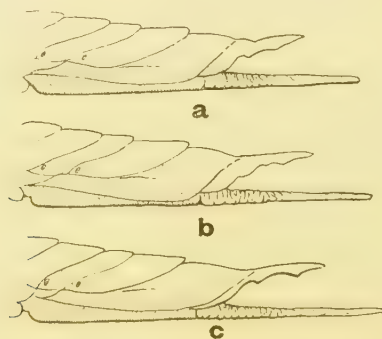


Fig. 1. Lateral view of ovipositors of *Sirex* to show different proportions of apical portion (sawsheath) to basal portion (oblong plate): (a) *Sirex noctilio*, F.; (b) *S. juvenicus*, L.; (c) *S. cyaneus*, F.

These two ratios (the ovipositor/forewing and the sawsheath/ovipositor) were selected partly because they appear to approach a constant value for each race, which is independent of the total size of the insect. This last characteristic is very important because of the enormous range in total size which may occur in these insects as in so many wood-borers. It is proved by plotting the logarithms of the ovipositor/forewing ratios against the log. of the forewing lengths and the log. of the sawsheath/ovipositor ratios against the log. of the ovipositor lengths for each race; in each case, where this was done, the result was a straight line at 45° .

The ratios were measured in all the specimens of all the species available, and their means and standard errors were calculated. The results are given in Tables I-III.

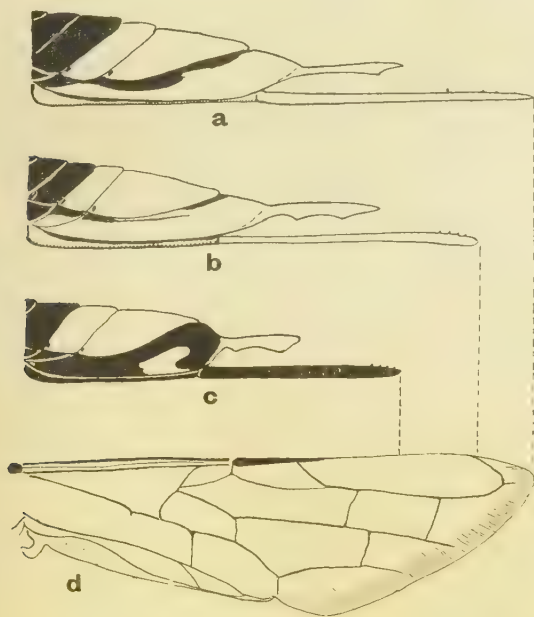


Fig. 2. Lateral view of ovipositors of three races of *Urocerus gigas*, L., comparing their lengths with that of a forewing: (a) *Urocerus gigas argonaularum*, Sem.; (b) *U. gigas gigas*, L.; (c) *U. gigas taiganus*, subsp. nov.; (d) forewing.

These Tables are provided in the hope that the ratios will become standard characters in future work on SIRICIDAE. Unfortunately the necessary measurements for estimating the sawsheath/ovipositor ratios have never been given in previous descriptions and those for the ovipositor/forewing ratios only for the species described by Semenov-Tian-Shanskii (1921), Conde (1935) and Takeuchi (1938).

No obvious inverse correlation was found between mean total size of a species and its ovipositor length (Table I). Presumably, therefore, if the length of ovipositor indicates the depth of oviposition in wood, then the oviposition habits must differ between the species.

The asterisks* in the Tables indicate that the ratios for those particular specimens were calculated from these published measurements and not from actual specimens before me.

Measurements were made to the nearest 0.5 mm.

TABLE I.

	No.	Mean forewing mm.	Mean ovipositor mm.	Mean ov. : fw. ratio (Table II)	Mean sawsh. : ov. ratio (Table III)
SIRICINAE—					
<i>Sirex areolatus</i> , Cress.	(1)	21.0	21.0	1.00	1.55
<i>S. cyaneus</i> , F.	(21)	21.5	18.0	1.19	1.85
<i>S. dux</i> , Sem.	(1+1*)	23.0	21.5	1.07	1.85
<i>S. edwardsi</i> , Brullé	(3)	19.5	13.0	1.47	2.27
<i>S. erna</i> , Sem.	(1)	13.0	11.0	1.18	2.00
<i>S. imperialis</i> , Kirby	(2)	20.0	15.5	1.29	2.10
<i>S. juvenis</i> , L.	(9)	20.0	15.0	1.34	2.00
<i>S. nigricornis</i> , F.	(3)	18.0	11.5	1.54	2.20
<i>S. noctilio</i> , F.	(28)	20.0	13.5	1.47	2.10
<i>S. tianshanicus</i> , Sem.	(1)	15.5	13.5	1.15	2.00
<i>S. varipes</i> , Wlk.	(1)	18.0	14.0	1.29	2.00
<i>Siricosoma tremecoides</i> , Forsius	(1)	22.5	15.5	1.44	2.20
<i>Urocerus albicornis</i> , F.	(9)	18.0	15.5	1.19	1.76
<i>U. antennatus</i> , Marlatt	(2)	21.0	22.0	0.96	1.65
<i>U. augur</i> , Klug	(6)	25.5	24.5	1.03	1.64
<i>U. californicus</i> , Norton	(4)	25.5	22.5	1.13	1.65
<i>U. cressoni</i> , Norton	(2)	18.0	14.0	1.27	1.95
<i>U. fantoma</i> , F.	(3)	21.0	15.0	1.41	1.90
<i>U. gigas argonautarum</i> , Sem.	(3)	20.5	20.5	1.00	1.70
<i>U. g. flavicornis</i> , F.	(20)	22.5	18.0	1.25	1.81
<i>U. g. gigas</i> , L.	(27)	24.0	20.5	1.11	1.70
<i>U. g. taiganus</i> , subsp. n.	(8)	24.0	18.5	1.30	1.85
<i>U. g. tibetanus</i> , subsp. n.	(2)	26.0	20.0	1.30	1.75
<i>U. japonicus</i> , Smith	(5)	22.5	21.0	1.05	1.68
<i>U. multifasciatus</i> , Tak.	(1+1*)	20.5	21.0	0.98	1.60
<i>U. niger</i> , sp. n.	(1)	29.5	28.5	1.04	1.60
<i>U. taxodii</i> , Ashm.	(2)	20.0	22.0	0.90	1.60
<i>U. umbra</i> , Sem.	(2*)	25.5	23.5	1.10	—
<i>U. xanthus</i> , Cam.	(5)	20.0	19.5	1.04	1.49
<i>Xeris himalayensis</i> , Bradley	(1)	21.5	30.5	0.71	1.30
<i>X. morrisoni</i> , Cress.	(1)	16.5	23.5	0.70	1.30
<i>X. spectrum</i> , L.	(13)	17.0	23.5	0.72	1.30
<i>Xoanon mysta</i> , Sem.	(1)	25.0	25.0	1.00	1.60
TREMECINAE—					
<i>Eriotremex formosanus</i> , Mats.	(1)	21.0	17.5	1.20	2.80
<i>E. insignis</i> , F. Smith	(1)	18.5	13.0	1.42	2.90
<i>E. smithi</i> , Cam.	(2)	17.0	13.5	1.24	2.70
<i>Tremex alchymista</i> , Mocs.	(1)	15.5	12.0	1.29	2.05
<i>T. apicalis</i> , Mats.	(1*)	22.5	20.5	1.11	—
<i>T. columba columba</i> , L.	(19)	23.0	20.5	1.15	2.28
<i>T. fuscicornis</i> , F.	(3)	21.5	18.0	1.21	2.36
<i>T. jakovlevi</i> , Sem.	(1*)	22.0	17.0	1.29	—
<i>T. longicollis</i> , Konow	(1)	26.0	21.0	1.24	2.70
<i>T. magus</i> , F.	(1)	21.5	17.5	1.23	2.20
<i>T. simulacrum</i> , Sem.	(1*)	22.5	18.5	1.22	—

TABLE II.
Ovipositor/Forewing Ratios.

	No.	Mean	Max.	Min.	Standard error
<i>S. nigricornis</i>	(3)	1.54	1.60	1.47	—
<i>S. noctilio</i>	(28)	1.47	1.62	1.35	0.011
<i>S. edwardsi</i>	(3)	1.47	1.52	1.41	—
<i>Siricosoma tremecoides</i> ...	(1)	1.44	—	—	—
<i>E. insignis</i>	(1)	1.42	—	—	—
<i>U. fantoma</i>	(3)	1.41	1.47	1.36	—
<i>S. juvenicus</i>	(9)	1.34	1.47	1.32	0.020
<i>U. gigas taiganus</i>	(8)	1.30	1.35	1.23	0.014
<i>U. g. tibetanus</i>	(2)	1.30	1.35	1.25	—
<i>S. imperialis</i>	(2)	1.29	1.32	1.25	—
<i>S. varipes</i>	(1)	1.29	—	—	—
<i>T. jakovlevi</i>	(1*)	1.29	—	—	—
<i>T. alchymista</i>	(1)	1.29	—	—	—
<i>U. cressoni</i>	(2)	1.27	1.31	1.22	—
<i>U. gigas flavicornis</i>	(20)	1.26	1.37	1.14	0.012
<i>E. smithi</i>	(2)	1.24	1.25	1.22	—
<i>T. longicollis</i>	(1)	1.24	—	—	—
<i>T. magus</i>	(1)	1.23	—	—	—
<i>T. simulacrum</i>	(1*)	1.22	—	—	—
<i>T. fuscicornis</i>	(3)	1.21	1.29	1.15	—
<i>E. formosanus</i>	(1)	1.20	—	—	—
<i>U. albicornis</i>	(9)	1.19	1.35	1.11	0.025
<i>S. cyaneus</i>	(21)	1.19	1.27	1.10	0.010
<i>S. ermaki</i>	(1)	1.18	—	—	—
<i>S. tianshanicus</i> ...	(1)	1.15	—	—	—
<i>T. columba columba</i>	(19)	1.15	1.19	1.04	0.009
<i>U. californicus</i>	(4)	1.13	1.17	1.06	—
<i>U. gigas gigas</i>	(27)	1.11	1.17	1.06	0.006
<i>T. apicalis</i>	(1*)	1.11	—	—	—
<i>S. umbra</i>	(2*)	1.08	1.13	1.02	—
<i>S. dux</i>	(1+1*)	1.07	1.09	1.04	—
<i>U. japonicus</i>	(5)	1.05	1.08	1.04	—
<i>U. niger</i>	(1)	1.04	—	—	—
<i>U. xanthus</i>	(5)	1.04	1.12	0.98	—
<i>U. augur</i>	(6)	1.03	1.14	1.00	—
<i>S. areolatus</i>	(1)	1.00	—	—	—
<i>U. gigas argonautarum</i>	(3)	1.00	1.02	0.98	—
<i>Xoanon mysta</i>	(1)	1.00	—	—	—
<i>U. multifasciatus</i>	(1+1*)	0.98	0.98	0.97	—
<i>U. antennatus</i>	(2)	0.96	0.98	0.93	—
<i>U. taxodii</i>	(2)	0.90	0.94	0.86	—
<i>X. spectrum</i>	(13)	0.72	0.81	0.59	0.017
<i>X. himalaënsis</i>	(1)	0.71	—	—	—
<i>X. morrisoni</i>	(1)	0.70	—	—	—

TABLE III.
Sawsheath/Ovipositor Ratios.

	No.	Mean	Max.	Min.	Standard error
<i>E. insignis</i>	(1)	2.90	—	—	—
<i>E. formosanus</i>	(1)	2.80	—	—	—
<i>T. longicollis</i>	(1)	2.70	—	—	—
<i>E. smithi</i>	(2)	2.69	2.70	2.68	—
<i>T. fuscicornis</i>	(3)	2.36	2.43	2.30	—
<i>T. columba columba</i>	(19)	2.28	2.50	2.10	0.027
<i>S. edwardsi</i>	(3)	2.27	2.29	2.15	—
<i>S. nigricornis</i>	(3)	2.20	2.28	2.15	—
<i>Siricosoma tremecoides</i>	(1)	2.20	—	—	—
<i>T. magus</i>	(1)	2.20	—	—	—
<i>S. noctilio</i>	(28)	2.12	2.30	2.06	0.011
<i>S. imperialis</i>	(2)	2.10	2.15	2.06	—
<i>T. alchymista</i>	(1)	2.07	—	—	—
<i>S. ermah</i>	(1)	2.00	—	—	—
<i>S. juvencus</i>	(9)	2.00	2.00	2.00	—
<i>S. tianshanicus</i>	(1)	2.00	—	—	—
<i>S. varipes</i>	(1)	2.00	—	—	—
<i>U. cressoni</i>	(2)	1.93	2.00	1.85	—
<i>U. fantoma</i>	(3)	1.89	1.93	1.88	—
<i>S. cyaneus</i>	(21)	1.84	1.93	1.75	0.011
<i>U. gigas taiganus</i>	(8)	1.84	1.88	1.67	0.015
<i>S. dux</i>	(1)	1.83	—	—	—
<i>U. gigas flavicornis</i>	(20)	1.81	1.93	1.74	0.014
<i>U. albicornis</i>	(9)	1.76	1.80	1.71	0.013
<i>U. gigas argonautarum</i>	(3)	1.72	1.73	1.71	—
<i>U. gigas gigas</i>	(27)	1.70	1.78	1.60	0.008
<i>U. japonicus</i>	(5)	1.68	1.72	1.65	—
<i>U. californicus</i>	(4)	1.65	1.70	1.59	—
<i>U. antennatus</i>	(2)	1.64	1.64	1.63	—
<i>U. augur</i>	(6)	1.64	1.68	1.60	—
<i>U. taxodii</i>	(2)	1.61	1.65	1.50	—
<i>Xoanon mysta</i>	(1)	1.60	—	—	—
<i>U. multifasciatus</i>	(1)	1.58	—	—	—
<i>U. niger</i>	(1)	1.58	—	—	—
<i>S. areolatus</i>	(1)	1.57	—	—	—
<i>U. xanthus</i>	(5)	1.49	1.65	1.30	—
<i>X. spectrum</i>	(13)	1.29	1.36	1.21	0.013
<i>X. himalayensis</i>	(1)	1.28	—	—	—

(c) The Genera.

In the key to the World genera, use has been made of several characters not previously noticed and a new genus is introduced for some of the Oriental species heretofore regarded as belonging to *Tremex*.

The subfamilies SIRICINAE and TREMECINAE seem to be valid groups supported by biological differences: the former, for instance, is, so far as is known, entirely attached to coniferous trees and the latter to angiospermous trees.

The actual host records are still very scanty, but at least the common widely distributed SIRICIDAE seem very tolerant as to the actual genus and species or even family of tree attacked, so long as the wood is in a suitable condition for the growth of the symbiotic fungi (see Francke-Grosmann, 1939).

(d) The Species.

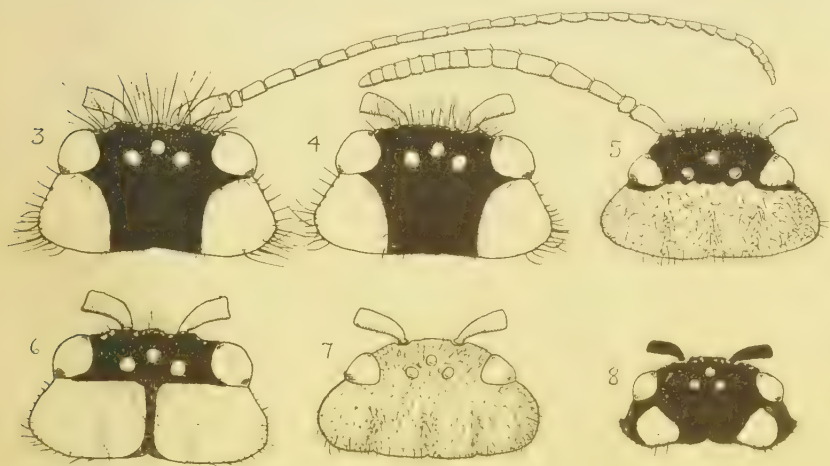
A catalogue of the species of SIRICIDAE of the World appeared recently as part 6 of the *Hymenopterorum Catalogus* edited by H. Hedicke (1938). In this can be found

references to many of the species or subspecies dealt with here, but obviously the specimens on which these records are based will have to be re-examined in the light of these new discoveries. Collecting in the less known parts of the world, especially, for instance, in the mountains of central and south-west Asia and the Himalayas, will probably reveal more species (or subspecies) than are known at present.

Unfortunately, in the systematic studies that follow, keys to the males of the species could not be given as so few specimens of them have been available for study. With the help of the present paper, it should now be possible to name correctly females of most SIRICIDAE by using the various faunistic works: keys to the Nearctic species were given by Bradley (1913), to the Palearctic species by Gussakovskii (1935), while the species of the Japanese Empire were given by Takeuchi (1938). As there are no known native SIRICIDAE in Australia or South America and only *Tremex hyalinatus*, Mocsáry, in the Ethiopian region, the world is fairly well covered by modern revisions except for the Oriental region and the Himalayas; the last section of the present paper is therefore devoted to this area.

KEY TO THE GENERA OF THE WORLD.

1. *Antennae* (fig. 3) *filiform and long* (would reach beyond base of stigma if stretched along forewing from tegula) *and set close together* (except in *Siricosoma*) (so that the distance between them is about $1\frac{1}{2}$ times as great as the distance between one of them and the nearest eye margin); *eyes* (except in *Xoanon*) *not more than $1\frac{1}{2}$ times as broad as long*; *labial palps* 3-segmented; *cerci* usually present; *cenchri* about twice as broad as long; *anal cell of forewing* contracted from about the middle (fig. 11) (except in *Siricosoma*, fig. 12). [Attached to coniferous trees.] (SIRICINAE).....2
- Antennae* (fig. 5) *slightly swollen in middle and short* (would not reach as far as base of stigma) *and set very far apart* (so that the distance between them is at least about 3 times as great as the distance between one of them and the nearest eye margin); *eyes* at least twice as broad as long; *labial palps*

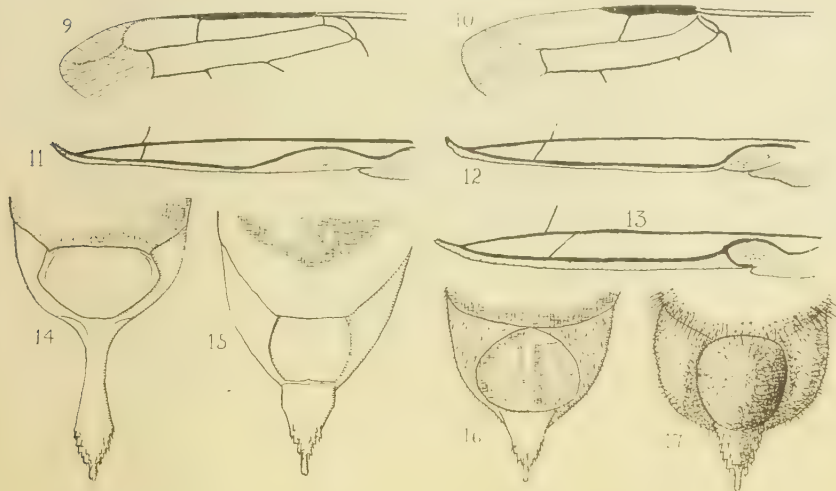


Figs. 3-8. Head from above to show general form, colour pattern and pubescence in *Urocerus gigas tibetanus*, subsp. nov., with an antenna (fig. 3), *U. gigas taiganus*, subsp. nov. (fig. 4), *Tremex fuscicornis*, F., with an antenna (fig. 5), *Urocerus augur*, Klug (fig. 6), *Xoanon mysta*, Sem. (fig. 7), and *Xeris spectrum*, L. (fig. 8).

- 2-segmented; cerci absent (except in *Eriotremex*); cenchri about as long as broad; anal cell of forewing contracted only in basal third (fig. 13). [Attached to angiosperm trees.] (TREMECINAE) 6
2. Head above entirely pale or with at least a pale spot behind each eye (figs. 3, 4, 6, 7 and 8); cornus of female constricted towards base (fig. 14); forewing with 1st transmedian vein represented by at most a stump.....3
- Head without any pale colour above and behind the eyes; cornus of female not constricted towards the base (fig. 15); forewing with the 1st transmedian vein present, but otherwise venation and head structure as in *Urocerus*, Geoffroy. Hind tibia with two apical spurs; eyes about $1\frac{1}{2}$ times broader than long. [Holarctic and Oriental; type: *Sirex juvenicus*, L.; ? 19 spp.].....
- Sirex**, Linnaeus
3. Head without a lateral carina behind the eyes (figs. 3, 4, 6 and 7) and hindwing usually with a closed anal cell; ovipositor at most scarcely longer than forewing; eyes about $1\frac{1}{2}$ times broader than long.....4
- Head with a lateral carina behind the eyes (fig. 8); hindwing without a closed anal cell; ovipositor about $1\frac{1}{2}$ times as long as a forewing; eyes almost round. [Hind tibia with only one apical spur; head sculpture and venation otherwise as in *Urocerus*, Geoffr.; Holarctic; type: *Ichneumon spectrum*, L.; 4 spp.].....
- Xeris**, Costa sent to
4. Antennae set far apart (so that they are about 3 times as far apart as either is from the nearest eye-margin); ocelli close together (so that POL:OOL is as about 1:1.5); anal cell of forewing contracted only within the basal 3rd (fig. 12); hind tibia with but one apical spur. [Malaya type: *Siricosoma tremecoides*, Fors.; monotypic.].....**Siricosoma**, Forsius 1934
- Antennae set closer together (so that they are only about $1\frac{1}{2}$ times as far apart as either is from the nearest eye-margin); ocelli further apart (POL usually greater than OOL); anal cell of forewing with the basal contraction beginning at about the middle of the cell (fig. 11); hind tibia with two apical spurs.....5
5. In the forewing 2nd and 3rd cubital cells (except when fused) each receive a recurrent vein: eyes not more than $1\frac{1}{2}$ times longer than broad; the pale spot on the genae behind the eyes shining with sparse punctures and pubescence (figs. 3, 4 and 6). [Holarctic and Oriental; type: *Ichneumon gigas*, L. ? 18 spp. and subsp.].....
- Urocerus**, Geoffroy (= *Xanthosirex*, Semenov, **syn. nov.**)
- In the forewing the 2nd transverse cubital vein has shifted apicad so that both recurrent veins are received in the 2nd cubital cell; eyes about twice as long as broad; genae behind the eyes dull with dense punctures and pubescence (fig. 7).
- [E. Siberia and Japan; type: *Xoanon mysta*, Sem. 1921. ? 2 spp.—Takeuchi (1938) places this as a synonym of *Sirex matsumurae*, Rohwer 1910 (Japan), which I have not seen. Rohwer says "hair of head and thorax mostly black"; in the specimen before me, from Ussuri, a female as Rohwer's was, a most striking feature is that the pubescence of the whole insect is yellowish-brown not black.].....**Xoanon**, Semenov 1921
6. Flagellum with 14 or more segments; hind legs in both sexes flattened but not greatly dilated; forewing usually with only two transverse cubital veins (figs. 9 and 10).....7
- Flagellum reduced to 3 segments; hind legs flattened, the tibiae and tarsi greatly dilated; forewing with three transverse cubital veins. [Not seen; Cuba; type: *Tremex cubensis*, Cress.; monotypic.].....**Teredon**, Norton

7. Transverse radial divides radial cell of forewing in two almost equal portions or nearer the apex than the base of the cell (fig. 9) ; ♀ abdomen with depressed disc on 9th tergite flat or longitudinally carinate, with very fine coriaceous surface and, together with tergites 7 and 8, only very finely pubescent (fig. 16) ; cerci entirely absent.

[*T. hyalinatus*, Mocs., from the Congo and Gabun has the radial cell of the forewing divided as in the following genus (cf. Guiglia 1937) and may belong to a distinct genus. Holarctic (but absent from Pacific S.R. of N. America) and Oriental (Manchurian and Indo-Chinese S.R.) ; type: *Sirex fuscicornis*, F. ? 13 spp.].....**Tremex**, Jurine



Figs. 9-17. Portion of left forewing to show division of radial cell in *Tremex fuscicornis*, F. (fig. 9) and *Eriotremex smithi*, Cam. (fig. 10). Portion of left forewing to show anal cell in *Urocercus gigas*, L. (fig. 11), *Siricosoma tremecoides*, Forsius (fig. 12) and *Tremex fuscicornis*, F. (fig. 13). Apex of female abdomen from above to show form of cornus and disc with pubescence and sculpture in *Urocercus gigas gigas*, L. (fig. 14), *Sirex juvenicus*, L. (fig. 15), *Tremex fuscicornis*, F. (fig. 16) and *Eriotremex smithi*, Cam. (fig. 17).

Transverse radial at about the basal 3rd of the radial cell of the forewing (fig. 10) ; ♀ abdomen with the depressed disc convex in the middle and strongly and coarsely punctured, and, together with the sides of tergites 7 and 8, densely hairy (fig. 17) ; cerci present in females.

[Oriental (Indo-Chinese and Malayan Subregions to New Guinea) ; type: *Tremex smithi*, Cam. (holotype) ; ? 8 spp.].....**Eriotremex**, gen. nov.

Sirex, L., with a Key to the Females occurring in Europe.

Enslin (1918), trying to use characters suggested by Konow (1905) in the length of the pronotum and colour of the basal segments of the antennae, failed to distinguish more than one species of *Sirex* in Europe. By making use of other characters, particularly the proportions between the sawsheath and oblong plate, all the female specimens in the British Museum collection were segregated easily into distinct species. Among other striking characters might be mentioned the black apical

tarsal segments on all the legs of both sexes of *S. noctilio*; it is astonishing that obvious characters of this sort can so easily be overlooked by worker after worker.

In the males there appear to be fewer characters available for separating the species. All have mainly red abdomens and black hind tibiae and tarsi. *S. cyaneus* and *juvencus* have reddish-yellow hind femora, reddish apical tergites and reddish-yellow apical tarsal segments, but the reddish-yellow bases of the antennae of *S. juvencus* should separate normal specimens of this species from *S. cyaneus*; *S. noctilio* has black hind femora, black apical tergites and a black apical tarsal segment to all legs.

1. Hind legs mostly black.....2
Hind legs mostly reddish-yellow.....3

2. Ovipositor about as long as forewing; sawsheath about $1\frac{1}{2}$ times as long as oblong plate; wings dark violaceous. [Occasionally introduced into Britain from N. America.]..... *areolatus areolatus*, Cress.

Ovipositor much shorter than forewing; sawsheath not longer than oblong plate (see Konow 1905, pp. 113-114); wings brownish, paler at bases. [Bavaria, Bohemia & Hungary.]..... *carinthiacus*, Konow.

3. All legs with the tarsus entirely reddish-yellow; sawsheath as long or longer than the oblong plate; mesopleura in the middle with shining interspaces larger than the punctures; ovipositor would reach from tegula to at least the middle of the radial cell of the forewing; middle tergites less densely wrinkled and shining laterally 4

All legs with the apical tarsal segment black; sawsheath shorter than the oblong plate (fig. 1a); mesopleura so densely punctured that in the middle there are no interspaces larger than the punctures; ovipositor would only reach to base of radial cell of forewing; middle tergites very densely wrinkled and not shining laterally.

[Ovipositor: forewing as about 1:1.47. N. and C. Europe, Siberia, N. Mongolia and Canada. Introduced into New Zealand.]...*noctilio*, F. (?=*atlantidis*, Ghigi 1909)

4. Sawsheath longer than oblong plate (fig. 1c); antennae apparently always entirely dark; ovipositor would reach at least almost to apex of radial cell of forewing from tegula.....5.

Sawsheath as long as oblong plate (fig. 1b); antennae typically reddish-yellow at base but entirely black in northern races; ovipositor would reach to about middle of radial cell of forewing (ovipositor: forewing as about 1:1.34).

[Typical race N. and C. Europe, Crimea, Caucasus, Siberia, Japan; dark form from N. Europe (including Scotland), Newfoundland and Canada.]...*juvencus*, L. (?=*sucineiceps*, Koornneef 1935)

5. Ovipositor not reaching to apex of radial cell of forewing (ovipositor: forewing as about 1:1.19). [N. America, and Europe, ? Asia.].....*cyaneus*, F.
Ovipositor reaching beyond apex of radial cell of forewing (ovipositor: forewing as about 1:1.07). [E. Transcaucasia.] *dux*, Sem.

Sirex carinthiacus, Konow.

I have not seen any representative of this species, and the characters are taken from Konow 1905, pp. 113-114.

Sirex noctilio, F. (and *atlantidis*, Ghigi 1909).

S. atlantidis, Ghigi 1909, from the Azores, was based on a single dwarf specimen (only 16 mm. long). In such dwarf specimens it is only to be expected that the head

would be less swollen behind the eyes. The very short sawsheath and dark apical tarsal segments ("pedibus piccis") indicate *S. noctilio*. Ghigi's description of *S. noctilio* as having the sawsheath "più lunga" than the oblong plate suggests that he had actually specimens of *S. cyaneus* before him to represent this species (see below).

S. noctilio has not previously been recorded from North America (cf. Bradley 1913). In the British Museum collection, however, there is a female of this species from Hudson's Bay, St. Martin's Falls, Albany River, G. Barnston (B. M. 1844-17). The proportion of sawsheath to ovipositor for this species is shown in Table III and fig. 1a.

Sirex juvencus, L. (and *sucineiceps*, Koornneef 1935).

S. sucineiceps, Koornneef 1935, was described from a single specimen found in Holland and probably derived from *Pinus* wood imported from North Russia. According to the description it differs from *S. juvencus* only in having a semi-transparent and amber coloured head. No indication of size is given but the description suggests an abnormal specimen in which the head is incompletely pigmented. The antennae in *S. juvencus* are normally reddish-yellow coloured at the base, and this has in the past been used as a specific character. The British Museum has several specimens in which the antennae are entirely black; these are actually all from northern localities: Labrador, Newfoundland, Murman Coast and Scotland. As they also have rather paler wings than typical *S. juvencus*, they may represent a distinct northern race belonging to the northern coniferous belt of both the Nearctic and Palaearctic regions and possibly endemic in Scotland. It is not, however, clear that they should receive any taxonomic status, as their nature is unknown. They may, for example, be the direct effects of climatic conditions or result from some gene favoured by such conditions.

At any rate, as no American writers make any mention of "*S. cyaneus*" with pale bases to their antennae, it would appear probable that the conspicuous typical form of *S. juvencus* does not occur in N. America. The following are the specimens I have seen of *S. juvencus* with all-black antennae:

MURMAN COAST, Yukanski, 1♀, 19.vii.1917 (*E. A. Cockayne*, B. M. 1918-9); BRITAIN, 1♀, Stephens Collection (B. M. 1853-46); NEWFOUNDLAND, 1♂, (*J. Milne*) (B. M. 1875-36); LABRADOR, Hopedale, 1♀, 11.ix.1935, (*W. H. Perrett* B. M. 1935-551); SCOTLAND (in the Royal Scottish Museum), Banffshire, 1♀, (1930-144).

In all the specimens of *S. juvencus* which I have examined, the sawsheath is almost exactly as long as the oblong plate (fig. 1b) cf. *S. tianshanicus*, Sem. I might here mention that the type of *S. varipes*, Wlk. 1866 (British Columbia) agrees very closely with *S. juvencus* in structure, but differs in having black tibiae to all the legs. It was quite wrongly synonymised with *S. cyaneus* by Konow 1905, and may perhaps be of the same species as *S. californicus*, Ashm. 1904, which I have not been able to see and which is very inadequately described.

Sirex tianshanicus, Semenov.

One female of this species was kindly given to the British Museum in exchange by Dr. V. V. Gussakovskii. The species was described from the mountains of Turkestan and appears to be only distinguishable from the forms of *S. juvencus* with entirely black antennae by its slightly longer ovipositor, which, if stretched along the forewing would reach from the tegula to near the apex of the apical radial cell. The ovipositor forewing ratio estimated from Semenov's figures (1917) (fw. 16-23 mm.; ov. 12-17.5 mm.) would give about 1:1.33, this would place it among the species with a very short ovipositor (see Table II). An estimate from the specimen in the British Museum gives 1:1.15. There is, therefore, something wrong with Semenov's figures as also with those of his *S. ermak* which give the same ratio.

Sirex cyaneus, F., and *S. dux*, Semenov.

S. cyaneus is very similar to *S. juvenus*, but differs in that the sawsheath is always longer than the oblong plate; the actual proportions are shown in Tables I and III and figure 1c. Although long recognised as an established species in Britain, it has heretofore always been regarded as native only to N. America. The description of *S. juvenus* in Konow (1905, pp. 336-7) and Ghigi (1909) show, almost certainly, that they had European specimens of *S. cyaneus* mixed with their representatives of *S. juvenus*; likewise all the Nearctic representatives of this species group have heretofore been called *S. cyaneus*, though actually, as indicated above, both *S. noctilio* and *S. juvenus* also occur there, at least in the Hudson zone.

S. dux, Sem. (represented in the British Museum by a single female given by Dr. V. V. Gussakovskii) differs from *S. cyaneus* only, so far as can be seen, in the slightly longer ovipositor compared to forewing. The forewing ovipositor ratio, as calculated from Semenov's figures (1917) (fw. 23; ov. 21), is 1.09; this agrees closely with the ratio as estimated from the specimen in the British Museum 1.04 (fw. 23; ov. 22). The figures are therefore combined in Table II.

Xeris, Costa.

X. spectrum, L., is a very widely distributed species of the northern coniferous belt and in mountainous regions further south in North America as well as in Eurasia, even in Turkestan, the Caucasus and Atlas Mountains. In spite of its enormous and discontinuous range, it has not yet been possible to define satisfactory geographical races; two other related species, however, occur in North America, and it is replaced in the Himalayas by a fourth species. The significance of it not becoming established in Britain despite its great tolerance of climate, as indicated in its wide distribution, is discussed on p. 44.

According to Francke-Grosmann (1939), *Xeris* is peculiar in that no symbiotic fungi have been found associated with it. Whether this is a primitive or advanced attribute is not clear.

Urocerus, Geoffroy, with a Key to the Females of the Species occurring in Europe.

In the males of the European species, the pale head will separate *U. angur* and *fantoma* from the rest (fig. 6); the former has no black markings on the abdomen and the latter a black apex. Of the others, *U. gigas gigas* and *argonautarum* are distinguished by their reddish 7th tergite—the abdomen being black only from the 8th—and by their entirely yellow antennae. *U. albicornis* and *gigas flavicornis* males are very similar, both having the abdomen black from the 7th tergite and the antennae black at the apex; the former, however, has a hind basitarsus 6.4 to 8.1 times as long as broad and the latter only 4.1 to 5.6 times as long as broad (Peck 1937).

1. Abdomen at least partly red or yellow.....2
 Abdomen entirely blue-black with at most lateral pale spots. [Wings smoky; antenna except apex and two or three basal segments, cheeks, sometimes lateral spots on abdomen, bases of tibiae and tarsi white; ovipositor would reach from tegula to middle of radial cell. North America, occasionally introduced into Britain but not established there.] *albicornis albicornis*, F.
2. Head yellow behind the eyes with at most a black longitudinal medial groove with sparse punctures each side (fig. 6).....3
 Head with the yellow spots widely separated by the black post-ocellar region, which is strongly punctured (figs. 3 and 4) [forms of *U. gigas*, L.].....4

3. Hind tibia with basal 2 3rds black ; abdomen with at least tergites 3 to 7 and 9 banded with black above ; claws with large subapical tooth (longer than its basal breadth) ; ovipositor reaching from tegula to beyond the apex of the radial cell of forewing. [Forms of *U. augur*, F.].....8
- Hind tibia all yellow with at most the extreme apex brown ; abdomen mostly yellow above with only tergites 6 and 7 banded apically with black and sometimes 4 and 5 with lateral spots ; claws with a minute subapical tooth (not longer than its basal breadth) ; ovipositor reaches only to first basal 3rd of the radial cell and is only about 2/3rds as long as the forewing. [Occurs in two widely separated provinces C. and E. Europe and again in W. Siberia.]*fantoma*, F. 1781 (= *tardigradus*, Cedj. 1796)
4. 9th tergite at least partly yellow above ; 8th tergite entirely yellow above.....5
- 9th tergite (excluding cornus) entirely black above and 8th tergite more or less black behind ; 9th sternite and ovipositor sheath entirely black externally. [Ovipositor/forewing ratio as about 1 : 1.26. Northern coniferous belt of N. America, occasionally introduced into Britain.].....*gigas flavicornis*, F.
5. 9th tergite above largely black, with at least the disc mostly black ; ovipositor-sheath dark (black or piceous) and if stretched along forewing (fig. 2c) would reach from tegula to a point halfway between the apex of the stigma and the apex of the radial cell (ovipositor/forewing ratio about 1 : 130).....6
- 9th tergite mostly yellow, with at least the disc entirely yellow, and, at most, black only on the basal margin ; ovipositor-sheath brown and would reach to apex of radial cell of forewing or beyond (fig. 2a and b) (ovipositor/forewing ratio as 1 : 1.11 or 1 : 1).....7
6. Hairs on head and thorax exceptionally long ; for instance those between the antennal sockets are longer than the first antennal segment (fig. 3) ; 2nd abdominal tergite mostly black behind. Himalayas. [TIBET : Zayul, Atakawg, 13,000 ft., 1♀ (holotype) 9.viii.1933 (*F. Kingdon Ward* & *R. J. H. Kaulback*) ; 28° 25' N., 97° 55' E., 10,000-12,000 ft. 1♂ (paratype), 11.ix.1931 (*F. Kingdon Ward*).]*gigas tibetanus*, **subsp. nov.**
- Hairs on head and thorax not abnormally long ; those between the antennal sockets, for instance, are little more than half as long as the first antennal segment (fig. 4) ; 2nd abdominal tergite entirely yellow. Finland, North Russia, Siberia and Japan.
- [FINLAND : 2 ♂♂ (including holotype), Watershed between 70° 0' - 70° 17' N. and 25° 50' - 26° 55' E., 1,000-2,000 ft., 19-20.vii.1938 and 1♀ near Kunes, Coastal area between 70° 17' - 70° 23' N. and 26° 40' - 26° 55' E., 23.vii.1938 (*A. F. O'Farrell*) (B. M. 1938-540). NORTH RUSSIA : Kola Gulf, 1♀, vii.1918 (*A. G. Carment*) (B. M. 1918-127). SIBERIA : 3 ♂♂, Cameron Coll. (B. M. 1896-76). S. W. Siberia : Kolpasievo, 1♀, 20.vii.1924 (*G. Bei Bienko*) (B. M. 1924-487). JAPAN : see fig. 23, plate V, Matsumura 1930.].....*gigas taiganus*, **subsp. nov.**
7. Ovipositor about as long as a forewing (fig. 2a). Caucasus, Transcaucasia and Asia Minor (1♀ in B.M. from Amanus Mts.)...*gigas argonautarum*, Sem. (**comb. nov.**)
- Ovipositor would reach only to about apex of radial cell of forewing from the tegula (ov./fw. ratio as 1 : 1.11) (fig. 2b). [C. and S. Europe, and Algeria ; introduced into S. America, Australia, etc.].....*gigas gigas*, L.
8. Abdominal tergites 7 entirely and 9 below black ; wings rich amber in colour with clearly defined infusate margins. [Atlas Mts. (♂ in B. M.), Caucasus and Mts. of N. Persia and Turkestan.*augur sah*, Moc. (**comb. nov.**)

Abdominal tergites 7 with lateral pale band and 9 pale below ; wings yellowish-hyaline without clearly defined infusate margins. [C. Europe and Asia Minor, occasionally introduced into Britain (Benson 1938).]...*augur augur*, Klug 1803 (= *cedrorum*, Smith 1860) (**syn. nov.**)

Urocerus albicornis, F., and *antennatus*, Marlatt.

Conde (1935, p. 68) suggests that *U. albicornis* of N. America is only a colour form of the East Asian *U. antennatus*. The two are, however, readily distinguished by the ovipositor/forewing and sawsheath/ovipositor ratios. Possibly they are really geographical fragmentations of one species and could be regarded as vicarious subspecies :

U. antennatus, Marl. 1898 : ovipositor longer than forewing (1 : 0.95) E. Asia.

U. albicornis, F. 1781 : ovipositor would only reach from tegula to middle of radial cell of forewing (ov./fw. ratio as 1 : 1.19) N. America.

Urocerus fantoma, F., and *xanthus*, Cameron.

U. fantoma, F. 1781 (= *tardigradus*, Cdj. 1796) occurs in two isolated provinces : C. and E. Europe and E. Siberia. Semenov (1921), solely on the basis of the small tooth it has to its tarsal claws, separates it into a distinct genus *Xanthosirex*, which I do not regard as valid. *U. xanthus*, Cam. 1876 (W. Himalayas) is very similar in colour and structure, but has a much stronger tooth to the claws and a longer ovipositor :

U. fantoma : ov./fw. ratio 1 : 1.41.

U. xanthus : ov./fw. ratio 1 : 1.04.

Urocerus gigas, L., and its subspecies.

Heretofore the two supposed species *U. gigas*, L., and *flavicornis*, F., have been separated only on differences of colour and country of origin. All Palaearctic forms were called *U. gigas* and all Nearctic forms *flavicornis*, the latter being always darker, and strikingly so when compared, as it usually is, with specimens from Central Europe. Bradley (1913) recognised the striking similarity between Nearctic and east Asian forms, and actually identified some forms from east Asia as belonging to the Nearctic species *U. flavicornis*. This appears to have been overlooked by later writers ; Gussakovskii (1935), Conde (1935) and Takeuchi (1938) for example treated the E. Asian form as typical *U. gigas*.

Conde, however, could find no morphological differences between the specimens he called *U. gigas* and those he called *U. flavicornis* ; he therefore suggested that the two should be regarded simply as two colour forms of the same species.

All workers seem to have overlooked the differences in ovipositor length (figs. 2*b* and *c*) ; this is all the more remarkable seeing that Semenov-Tian-Shianskii (1921) drew attention to ovipositor lengths by describing a third species *U. argonautarum* (Caucasus and Transcaucasia) on the basis of its exceptionally long ovipositor (fig. 2*a*). The proportional differences of the ovipositor/forewing ratio between *argonautarum* and *gigas* are actually less than between *gigas* and *taiganus* (the ov./fw. ratios in these three forms being 1 : 1, 1 : 1.11, and 1 : 1.30) ; *taiganus* is very similar to *flavicornis* in structure but has less developed dark markings, while *tibetanus* differs from *taiganus* only in the longer hairs on its head (fig. 3). These forms are obviously closely related to each other and are better regarded as subspecies of one species, with a tendency to darker pigmentation towards the east and a longer ovipositor in more southern climates.

Through the carriage of timber between different parts of Europe and N. America there appear to be a certain number of intermediates, especially in the areas where

taiganus and *gigas* meet—in Britain and north-east Europe (see p. 46). In computing the ov./fw. ratios of these two forms, British specimens were therefore excluded, as also were any continental specimens showing intermediate colour pattern.

The different lengths of ovipositors in these forms are correlated naturally with a very different general facies. In the forms with a longer ovipositor, the apex of the abdomen is much sharper and the basal sternites are more crowded together, with the effect that the apex of the hind femora will reach to the base of the ovipositor; in the forms with a shorter ovipositor, the apex of the abdomen is more obtuse and the hind femora do not reach as far as the base of the ovipositor.

Urocerus augur, Klug.

U. augur, Klug, is here regarded as consisting of two subspecies. *U. cedrorum*, Smith (Asia Minor) is not distinguished from the European *U. augur augur*, and it is difficult to understand why Konow, in his haste to be rid of it, should have placed it as a synonym of *U. fantoma*, F., a very different species. *U. sah*, Mocs. (on the basis of specimens so named by Gussakovskii) differs only in colour from typical *U. augur* and is relegated to the position of a subspecies. *U. japonicus*, Smith (holotype examined) is superficially very similar to typical *U. augur* and may be of the same stock, but, as pointed out by Takeuchi (1938), it differs from all other known SIRICIDAE in having no barbs on the apex of the ovipositor sheath.

The mean ovipositor/forewing ratio of the few specimens of *U. augur* examined is as 1 : 1.03; insufficient material was available to tell whether significant differences exist between the two races. In *U. japonicus*, Smith, the figure is approximately the same (1 : 1.05).

Tremex, Jurine, with a Key to the Males and Females of the Species occurring in Europe.

Unfortunately I have had only extremely limited Palaearctic material of this genus to work with. The most widespread species, *T. fuscicornis*, F., appears to be very closely related to the Nearctic *T. columba*, L., being somewhat intermediate in body colour between the dark *T. columba columba* (Bradley 1913) of the Central and Eastern States of U.S.A. and the paler bodied subspp., *sericea*, Say (Southern States) and *aurea*, Bradley (Rocky Mountains). West of the Rocky Mountains and in the northern zone *T. columba* does not apparently occur, owing presumably to the scarcity of hardwood trees, so that *T. columba* is widely separated geographically from the eastern limits of the present range of *T. fuscicornis* in Asia. Structurally the two species, on the basis of the limited material before me, can be separated as follows:—

T. columba, L. 1763: ocelli closer together, so that POL: OOL is less than 1: 1.5; Nearctic.

T. fuscicornis, F. 1787: ocelli further apart, so that POL: OOL is nearly 1: 2; Palaearctic.

T. magus, F., is not represented in the British Museum at all, but I have examined a pair in the Hope Department at Oxford. Of *T. alchymista*, Mocs., there is a single male and female in the British Museum. To this genus, as restricted above, belong — *T. alchymista*, Mocs. ♂ (Europe), *apicalis*, Mats. ♂ (Japan), *atratus*, Mocs. ♀ (Tonkin), *chujoi*, Sonan ♀ (Formosa), *columba*, L. ♂ (N. America), *fuscicornis*, F. ♂ (Europe and Siberia), *insularis*, Smith ♀ (Malay, holotype examined), *longicollis*, Konow ♀ (Japan), *jakovlevi*, Sem. ♀ (Transcaucasia), *magus*, F. ♂ (Europe) and possibly also *T. flavicollis*, Cam. ♀ (but see under *Eriotremex*): in addition the following were described only from males and may later be correlated with known females: *pandora*, Westw. ♂ (E. India and China), *satanas*, Sem. ♂ (Transbaikal and Ussuri) and *nigra*, Sonan ♂ (Formosa).

Tremex rugicollis, Westw. ♂ (Philippines) and *T. viridiceps*, Cam. ♂ (Borneo) were also described only from males: of these *T. viridiceps* is dealt with under *Eriotremex* where it may belong, but *T. rugicollis* (the type of which I have not seen) would appear from its long setiform antennae and two-spurred middle tibiae (Westwood 1874, plate 20, fig. 9) not to belong to the TREMECINAE at all. Konow (1905, p. 342) mentions that the left forewing of the figure of the type has four cubital cells and the right only three; this is not so in the copy of Westwood in the Tring Museum—both wings being figured here as having but three cubital cells.

T. hyalinatus, Mocs. (W. Africa: Congo and Gabon) has the transverse radial vein near the base of the radial cell, as in *Teredon*, Norton, and *Eriotremex*, gen. nov., and possibly represents still another genus, but no specimens have been available for study.

Key to European Tremex Jurine (Males and Females).

1. Antenna black, either with white apex (♀) or with entirely black legs (♂); wings at apices, or entirely, dark brown; hind ocelli close together (POL=OOL approximately).....2
 Antenna brown, more or less infusate at apex (♀), if entirely black (♂) legs are partly brown; wings yellowish; hind ocelli far apart (POL greater than $1\frac{1}{2}$ OOL); tarsal claws with large sub-basal tooth. [Europe and E. Siberia.] ♂♀ *fuscicornis*, F.
2. Wings entirely dark brown; abdomen black, in ♀ with only the middle sternites white-flecked, in ♂ with pale lateral margins to segments; tarsal claws with an obsolete sub-basal tooth, much shorter than its basal breadth. [Hungary.] ♂♀ *alchymista*, Mocsáry
 Wings only dark brown at their apices; abdomen black, in ♀ generally richly flecked with white above, but in ♂ entirely black; tarsal claws with a large sub-basal tooth longer than its basal breadth. [C. and S. Europe, S. Russia and Crimea.] ♂♀ *magus*, F.

Eriotremex gen. nov. with a Key to its Females.

♂♀. *Head* without lateral carina behind the eyes; labial palps 2-segmented; antenna swollen in middle and short (would not reach as far as base of stigma if stretched along the forewing from the tegula) and set very far apart (so that the distance between the antennal sockets is about three times as great as the distance between one of them and the nearest eye-margin); flagellum with more than 14 segments. *Forewing* with only two transverse cubital veins and with the transverse radial vein near the base of the radial cell (fig. 10) (the apical portion of the radial cell is about twice as long as the basal portion); anal vein at about half way from the base of the anal cell with a short projecting branch to the wing margin (as in *Tremex*, *Teredon* and *Xeris*, cf. fig. 13). *Cenchri* pear-shaped and scarcely broader than long. ♀ *Abdomen* with depressed disc on 9th tergite convex in the middle and (except in *T. flavicollis*, Cam., which may not belong here) strongly and coarsely punctured (fig. 17); small cerci present in ♀. *Pubescence* in ♀ very long and dense; on lower face it is longer than the 3rd antennal segment; on the abdomen it is developed more on the apical than basal segments, the sides of tergites 7 and 8 being clothed in long dense hairs.

Type: *Tremex smithi*, Cameron (holotype ♀) (E. India).

To this genus also belong *Tremex formosanus*, Mats. ♀ (Formosa and Indo-China), *T. insignis*, Smith ♀ (Aru), *T. konowi*, Lange ♀ (New Guinea), *Eriotremex malayanus*, sp. nov. ♂, ? *Tremex flavicollis*, Cam., ♀ (Assam), and ? *T. viridiceps*, Cam., ♂ (Borneo).

In the following key to females, *Tremex flavicollis*, Cam., is included because of its close superficial similarity to *E. formosanus*, Mats., although there is nothing else

in its original description to indicate that it belongs to *Eriotremex*. *Tremex viridiceps*, Cam. ♂ (Borneo) had to be omitted as its female has not been described (at any rate under this name) and its original description is entirely inadequate even to show its relationships—it is mentioned here as possibly a species of *Eriotremex* mostly for geographical reasons (but note that the Malayan *Tremex insularis*, Smith, has forewings of typical *Tremex*, but unfortunately the abdomen of the unique type in the Hope Department is missing). I have indicated above that the type of *Tremex viridiceps* is a male; this is not in accordance with the original description which describes it as female. A male labelled as type in Cameron's handwriting came to the British Museum from Cameron's collection (1914-110); the size, colour-pattern of abdomen and other data ("Kuching, Oct. 1906, J. H.") agree with the original description of the unique type. At the same time it seems almost incredible that a male Siricid could be mistaken for a female. That the mistake was not simply a wrongly placed "♀" sign is shown by the description of the produced hypopygium as "ovipositor short, narrow." Unfortunately the specimen is now in very bad condition, and has no forewings left, so that it cannot be placed generically. Its tarsal claws are without a sub-basal tooth, and this, with its pale pronotum, suggests a possible relationship with *E. malayanus*, sp. nov.

Key to Eriotremex gen. nov. Females.

1. Tarsal claws with a well-developed sub-basal tooth in addition to a slight basal lobe 2
 Tarsal claws without a sub-basal tooth ♀ not known, but ♂ has pronotum yellow above and wings smoky at least apically]...*viridiceps*, Cam. (Borneo) and *malayanus*, sp. nov. (Malay)
2. All pubescence yellow, so also are pronotum, tibiae and basitarsi (except at their apices), wings and at least three complete bands on dorsum of abdomen...3
 Pubescence on lower face and underside black, and either black or silvery white elsewhere; pronotum black; legs piceous; wings hyaline and/or smoky; dorsum of abdomen with at most one complete yellow band.....4
3. Abdomen with yellow bands narrow on bases of tergites 2 and 3, broad on tergite 5; scutellum smooth and shining; disc on apical tergite smooth and unpunctured; frons with a short tooth above the antennae. [Not seen. Assam. ? belongs to *Tremex*.]*flavicollis*, Cam.
 Abdomen with broad yellow bands on bases of tergites 2 and 8 and with narrow bands on bases of tergites 3 and 7; scutellum dull with close fine punctures as rest of mesonotum and profusely pubescent; disc on apical tergite dull with dense coarse punctures; frons without tooth above antennae. [Formosa and Indo-China.]*formosanus*, Takeuchi
4. Pronotum with a large smooth shining area each side; wings uniformly smoky; abdomen with tergites 5 to 9 smooth shining and almost impunctate and but sparsely pubescent above; all pubescence black.
 [The three forms placed here may prove to be no more than colour forms of one species. 5
 Pronotum dull all over with coarse warts and rugae; wings with at least hind pair largely hyaline; abdomen above dull all over with fine punctures and microsculpture and densely pubescent apically; pubescence black on lower face and underside generally but silvery white on upper face and dorsum of abdomen.
 [Abdomen all dark metallic blue or purple, or (type) with lateral basal pale marks more or less developed, especially on terga 2, 3, 7 and 8. Type and one other specimen in British Museum. Indo-Chinese subregion.]...*smithi*, Cam.

5. Abdomen with some of the basal tergites white-marked.....6
 Abdomen without pale markings. [Malay (Westwood 1874) ; N. Borneo (Forsius 1934 as "*Tremex insignis*, Smith") ; not seen.]...*purpureipennis*, Westw. 1874.
6. 1st tergite of abdomen with a narrow transverse fascia in the middle and the 2nd very narrowly white at the base. [Type in Hope Department seen. Aru.]*insignis*, Smith 1859.
 1st tergite of abdomen immaculate ; 2nd tergite with lateral basal broad white marks ; tergites 4 to 6 with basal medial triangular white masks. [Not seen. N. Guinea.].....*konowi*, Lange 1909.

Eriotremex malayanus, sp. nov.

This species was described by Forsius 1934, *Bull. Raffles Mus.* 5 pp. 172-173, following his note on "*Tremex insularis*, Smith." Unfortunately the name heading his new species was omitted! Among the type specimens from this collection, that came to the British Museum, is the one here described as it bears a manuscript label in Forsius's handwriting "*Tremex malayana* n. *Holotypus*. det." Hedicke (1938) unfortunately has already taken the description to refer to the male of *T. insularis*, Smith. This is manifestly impossible from the text, for had this been Forsius's view he would have scarcely described the male as "*holotypus*" and mentioned that the female was unknown.

In the key above, I have drawn attention to a rather important character, not mentioned by Forsius, the fact that the tarsal claws of this new species have no sub-basal tooth ; a character which, together with a pale pronotum, it shares with *Tremex viridiceps*, Cam., ♂ (which may also belong to *Eriotremex*). *T. viridiceps* can easily be distinguished by the pale markings on the abdomen. It might here be mentioned that *Tremex alchymista* (but not *magus* ; see under *Tremex* above) and *T. pandora* (Westwood's type ♂ in the Hope Department) also have claws without a sub-basal tooth.

Eriotremex formosanus, Matsumura.

A single female in the British Museum collected by R. V. de Salvaza in Indo-China, Haut Mekong, Vien Poukha, 11.v.1918, agrees closely with the redescription and figure of this species given by Sonan 1938 (pp. 93-94 and fig. 3).

It would appear, therefore, that this species is not limited to Formosa, but has a wider oriental distribution.

In colour the species appears to be rather similar to *Tremex flavicollis*, Cam. (Assam), but the very different sculpture suggests that the latter does not belong to *Eriotremex* at all.

BRITISH SIRICIDAE.

(a) Recorded British Species.

Waterston (in Chrystal 1928) regarded *Urocerus gigas*, L., *Sirex cyaneus*, F., ? *S. juvenicus*, L., and *S. noctilio*, F., as established British species. Species occurring occasionally but not apparently established he lists as : *U. albicornis*, F. (Nearctic), *U. flavicornis*, F. (Nearctic) and ? *augur*, Klug (C. Europe). *U. augur*, Klug (= *cedro-rum*, Smith) is confirmed by Benson 1938. To these must be added *Neris spectrum*, L. (Roebuck 1906 and Saunt 1925) and *Sirex arcuatus*, Cresson (Saunt 1925).

(b) Is there a Native Siricid Element in Britain ?

Waterston and others have assumed that none of these species was truly native in Britain. At the same time it must be remembered that the old Caledonian forest is

simply an extension of the great circumpolar northern coniferous belt, the taiga, and that where the forest could spread so probably could the SIRICIDAE, and that two or three species are able to flourish in our climate to-day.

There seems no reason why we should necessarily assume that any post-glacial native element would have been exterminated with the great destruction of the ancient forests in Scotland, Ireland or even in England. For even in England conifers were being planted before the end of the 17th century (Tansley 1939, pp. 181-189); that is to say before the native conifer forests in England were entirely destroyed. If our plantations are so readily infected, as has been assumed, by SIRICIDAE emerging from imported timber, could they not have been infected by native SIRICIDAE from the old forest relics? Admittedly timber was being imported in quantity into north-east Britain from north Europe by the 13th and 14th centuries, and our species may easily have been brought in then. But, if this is so, why of all the species brought in should the common *Xeris spectrum*, L., with the widest geographical distribution, and therefore presumably the greatest tolerance, never have succeeded in establishing itself, though known to have been introduced?

(c) Is there a native British Form of *Urocerus*?

Among the British *Urocerus* in the British Museum there is one specimen from Perthshire, Murthly, 15.vii.1909, with an ovipositor forewing ratio of 1:1.24, that is to say within the known range of *U. gigas taiganus*, but coloured as in normal *U. gigas*. In the Royal Scottish Museum Collection I was able to find two more specimens with a short ovipositor, one labelled "Aberdeen 1925-134" and the other "Whittingham, E. Lothian"; in both these the ovipositor forewing ratio is 1:1.23 and, furthermore, they approach *taiganus* in colour, both having the 9th tergite broadly black at the base and the ovipositor black. Similar specimens occur in the British Museum from other northern localities, Norway, Lapland, etc. Because of these specimens, British and pale northern forms were excluded from the statistics in Table II, as it was thought they might indicate hybridisation between the two sub-species.

Such a possibility is further suggested when specimens from Scotland, England and Central Europe are treated separately for ovipositor/forewing ratios:—

	No.	Mean	Max.	Min.	Standard error
(a) Scotland	16	1.16	1.24	1.05	0.012
(b) England	28	1.13	1.19	1.07	0.007
(c) Central Europe	27	1.11	1.17	1.06	0.006

Between samples (a) and (b) this difference is significant when the appropriate tests are applied ($P=0.01$): between (b) and (c), however, the significance is less certain ($P=0.056$ to 0.02).

If, furthermore, we examine the colour, taking, for example, the colour of the ovipositor sheaths, we find it is black to dark brown in all specimens of *U. gigas taiganus* and brown in typical *U. gigas gigas*, but that dwarf specimens of *U. gigas gigas* (with forewing length of less than 16 mm.) have a dark sheath and approach *taiganus* generally in colour.

If now we divide the above specimens according to whether the ovipositor sheath is black to dark brown or dark brown to brown (omitting dwarfs), we get:—

						Total	Sheath dark
Scotland ...	...	...	...	...	...	16	8=50%
England ...	...	...	...	...	...	26	0=0%
C. Europe	...	...	...	...	...	23	4=17.4%

When the ovipositor/forewing ratios were compared between the eight dark and eight light Scotch specimens both gave the same mean result : 1.16 ! This suggests that there is no evidence of correlation between short sheath and dark sheath.

From the above it is clear that there is a significantly larger proportion of darker specimens and specimens with shorter ovipositors in samples from Scotland than in samples from England and Central Europe. This may be the direct result of climatic conditions in Scotland, within historic times, favouring the survival there of individuals showing these tendencies in imported stocks of *U. gigas gigas*, or it may indicate the presence in Scotland of a different race. Such a race may have survived as an endemic element in the northern British coniferous forests; alternatively, a *taiganus* or *flavicornis* element may have been established from importations of North European or American origin, and have been able to survive more readily in our northern forests than *U. gigas* introduced from a more southern latitude.

Unfortunately I have not been able to examine any SIRICIDAE known to have been captured in any Caledonian forest relic. Any such specimens would naturally be of very great interest in this connection.

(d) Is the dark Form of *Sirex juvencus* native in Britain?

As indicated above, *Sirex juvencus*, though normally having brownish-yellow bases to the antennae, occurs in the extreme north (Murman Coast, Labrador and Newfoundland) in a form in which the antennae are entirely black. In the Royal Scottish Museum there is a similar specimen from Banffshire.

Of the typical form of *S. juvencus* I have seen no Scotch specimens, the only British ones being from Southern England.

W. Evans (1922) had likewise seen no typical *S. juvencus* when he discussed the distribution of SIRICIDAE in Scotland. Waterston (1928) doubted whether "*S. juvencus*" was established in Britain. A re-examination of the material in collections is now called for, as, even in the British Museum collections, all the specimens of *S. juvencus* with dark antennae had been placed by previous workers as *S. cyaneus* or *S. noctilio*. Further British specimens of the dark form of *S. juvencus* may well exist in collections and their discovery might throw more light on its possible significance.

THE SIRICIDAE WERE NOT DERIVED FROM THE JURASSIC PSEUDOSIRICIDAE.

In the SIRICIDAE, as in some other orthandrious sawflies, the more generalised forms (SIRICINAE) are attached to coniferous trees and the more specialised (TREMECINAE) to angiosperm trees. The SIRICINAE are spoken of as more generalised because, in their antennae, mouth-parts, venation and cerci, they differ from the TREMECINAE by being less reduced and thus more like the earliest known fossil insects.

With the help of Dr. F. E. Zeuner, I examined the type of *Megapterites mirabilis*, Cockerell (Eocene); here also the cross veins are evidently reduced, though, beyond part of the forewings, nothing is preserved to indicate that the insect was even Siricoid. When we come, therefore, to the PSEUDOSIRICIDAE (an extinct fossil

family common in the Upper Jurassic of Solenhafen, Bavaria) we are surprised to find that, though they are remarkably similar to SIRICIDAE in general form, the cross-veins in the forewings have been in some respects, even here, further reduced than in modern *Tremex* (cf. Tillyard 1927, figs. 1 & 2).

Now it is unlikely that the cross-veins, after being lost in the Jurassic PSEUDOSIRICIDAE, would have been regained in modern sawflies. That these cross-veins are (contrary to Tillyard's view) of great antiquity, is suggested in comparing the wings of modern Megaloptera with modern XYELIDAE (as was done by Ross 1936) or with Martynov's figure of the forewing of *Liadoxyela* (Lower Jurassic) (Martynov 1937)—the earliest known Hymenopteron: not only the number but also even the positions of these cross-veins are shown to be almost identical!

This leads to the conclusion that the PSEUDOSIRICIDAE (U. Jurassic) and *Megapterites* (Eocene) were not in the direct line of any modern sawfly group and could not have been the progenitors of the SIRICIDAE.

HIMALAYAN AND ORIENTAL SIRICIDAE.

Sonan (1938) describes some species known to him in Formosa; any of these Formosan species (see *Eriotremex formosanus*, Mats., above, and *Urocerus multifasciatus*, Takeuchi, below) may be widespread Oriental species.

Urocerus koshuna, Sonan (apparently close to *U. multifasciatus*).

U. nitakana, Sonan, with its var. *tsutsujiyamana* (may be forms of *U. japonicus*, Smith—a species rather variable in colour but distinguished from all other *Urocerus* by the absence of barbs near the apex of the sawsheath).

Tremex chujoi, Sonan (? related to *T. longicollis*, Konow, of Japan).

T. nigra, Sonan (? male of *T. chujoi*).

Apart from *Siricosoma*, *Tremex* and *Eriotremex*, which have been dealt with above, the following Oriental and Himalayan SIRICIDAE are represented in the British Museum:—

Xeris himalayensis, Bradley 1934.

This species was described from a single pair taken at about 9,000 ft. in the United Province. In the British Museum there is a female from Kashmir, near Gulmerg, 5,000–9,000 ft. (*J. E. T. Aitchison*) (B. M. 1896 255). Takeuchi (1938) records the widespread *X. spectrum*, L., from Formosa.

Urocerus xanthus, Cameron 1876.

In addition to the holotype from "North India" the British Museum contains specimens taken from 5,000–9,000 ft. in Kashmir and in Punjab. For comparison with *U. fantoma* see discussion above under that species.

U. gigas tibetanus, **subsp. nov.**

This form from Tibet is closely allied to the northern-coniferous-belt *U. gigas taiganus*, subsp. nov., and is included for this reason in the key above to the European *Urocerus*.

U. multifasciatus, Takeuchi 1938.

In the British Museum there is a single female (from North Burma, Adang Valley, 12,000 ft., 23.viii.1931, *F. Kingdom Ward*), which agrees very closely with Takeuchi's description of the single specimen (from Formosa) which he made the basis of this species. The colour pattern is the same except that the Burma specimen has the mesonotum in the middle, the scutellum and the upper part of the mesopleura brown; as the ovipositor forewing ratio is also approximately the same (0.98–0.97) the two specimens are probably conspecific.

Unfortunately in Takeuchi's figure of his specimen (1938, p. 190, fig. 4) the ovipositor has been drawn much too long. My reason for saying this is that it does not agree with two independent measurements he gives:—

(i) He says that the ovipositor projects by 8 mm. beyond the tip of the cornus, which is 5 mm. long;

(ii) He says that the ovipositor extends "a little less than twice the length of the cornus beyond tip of the latter."

In his figure the ovipositor is drawn as extending more than three times the length of the cornus beyond the apex of the latter.

Urocerus niger, **sp. nov.**

♀. *Colour*: black with the following parts yellowish-white; head behind the eyes (except for the frons and a longitudinal vertical stripe about as wide as an eye); antennal segments 3 to 11 and the bases of 12 and 14; basal 2 5ths of front tibia; basal 1 3rd of front basitarsus; basal 3 4ths of middle and hind tibiae and basitarsi, and extreme bases of 2nd and 3rd tarsal segments of same. *Wings* fuscohyaline with black venation. *Size*: forewing 29.5 mm.; ovipositor 28.5 mm.; sawsheath 18 mm.; antenna 19.5 mm.; ov.: fw. ratio 1:1.04; sawsheath: ov. ratio 1:1.60. *Sculpture*: head with pale parts shining, almost impunctate and naked as in *U. augur*; rest of head and thorax dull and irregularly punctured; coarse on the hind parts of the mesonotum and on the mesopleura; very coarse on the pronotum above. Abdomen with terga 1 and 9 to 10 shining and almost impunctate; terga 2 to 8 dull with dense transverse rugulae, less developed on the apical 3rd of the terga and the whole of tergum 8. *Head* with a very deep medial vertical furrow; antenna 24 segmented; eyes small so that in dorsal view the length of the eye is about as long as half the length of the head behind the eye (in all other *Urocerus* spp. it is 2 3rds to 3 4ths this length). *Mesonotum* with a slight but distinct medial longitudinal furrow. Otherwise in structure including pubescence and wing-venation as in *Urocerus gigas gigas*.

S.E. Tibet, Zayul, 1♀, 7,000–12,000 ft., summer 1935 (*R. J. H. Kaulback*) (*B. M.* 1937–547).

In colour this species is apparently rather similar to the eastern Palearctic *Urocerus umbra*, Sem., and in the ovipositor, forewing ratio it agrees closely with this species (1:1.04 and 1:1.08). It differs, according to the description, in the following points: the antennae are black instead of pale at the apex; the venation is all black instead of being white at the base of the forewing; the wing membrane is fuscohyaline instead of brownish-yellow; the abdomen is entirely black instead of being yellow-flecked on the sides of terga 5 and 6.

The small eyes separate it from all other *Urocerus* spp. that I have examined (but I have not seen any *U. umbra*, Sem.). The rather similarly coloured *U. antennatus*, Marl. (Japan), *albicornis*, F. (N. America) and *taxodii*, Ashm. (N. America) differ, in addition, by having the pale naked spots on the head widely separated on the vertex.

Sirex imperialis, Kirby.

This species is represented in the British Museum by two specimens: the ♀ holotype from "N. India" and a ♂ from Punjab, Kangra Valley, 4,500 ft., June 1899 (*G. C. Dudgeon*).

Structurally it is very close to *S. noctilio* but differs in its entirely black legs, more strongly infuscated wings and less densely punctured mesopleura—punctured as in *S. juvenis*. It has a shorter sawsheath than the similarly coloured *S. ermak*, Sem. (China, Sze-tschuan) and *S. varipes*, Wlk. (British Columbia); from *S. carinthiacus*, Konow (W. Europe), *S. nitobei*, Mats. (Japan) and *S. mongolorum*, Sem. & Guss. (N. Mongolia), whose sawsheaths I have not had an opportunity of measuring, it differs

by having all its legs entirely black. It is apparently closely related to *S. vates*, Mocs. (China, Sze-tschuan), but this is described as having a dull black, not metallic abdomen. The Nearctic *S. edwardsi*, Brullé, has an even shorter sawsheath and together with *S. obesus*, Bradley, has a clearly shouldered cornus (Bradley 1913).

SUMMARY.

1. These studies were originally intended to form the basis of a world monograph of the SIRICIDAE; such a work cannot be completed under present circumstances.

2. Two ratios are introduced as useful characters for separating species: the ovipositor/forewing ratio and the sawsheath ovipositor ratio. These ratios were obtained from all specimens of all the species represented in the British Museum collections and the results are tabulated. They were found not to vary with the size of the insects.

The former ratio is specially useful in the genus *Urocerus*, which has a long ovipositor, and the latter ratio in the genus *Sirex*, which has a shorter ovipositor.

3. Keys are given to the genera of the world. Of Semenov's new genera, *Xoanon* is accepted but not *Xanthosirex*. A new genus *Eriotremex* is erected for certain Indo-Malayan species previously included in *Tremex*.

4. Keys are given to the European species, which are compared critically with related species from other parts of the world. A key to the species of *Eriotremex*, gen. nov., is also given.

5. *Sirex noctilio*, F., and *S. juvencus*, L., are recorded for the first time from North America and *S. evaneus*, F., from the continent of Europe. The common *Urocerus* of the northern Palaearctic region is shown to be more closely related to the Nearctic *U. gigas flavicornis*, F., than to the central European *U. gigas gigas*, L., and is treated as a new subspecies—*U. gigas taiganus*, subsp. nov. *U. gigas tibetanus*, subsp. nov., is described from the Himalayas. *U. šah*, Mocsáry, is treated as a subspecies of *U. augur*, Klug, and *U. cedrorum*, Smith, as a synonym of *U. augur augur*, Klug.

6. The British SIRICIDAE are discussed, and it is suggested that *U. gigas taiganus*, subsp. nov., and the form of *S. juvencus*, L., with entirely black antennae may be native in the Caledonian forest.

7. It is argued that modern SIRICIDAE could not have been derived from the Jurassic PSEUDOSIRICIDAE.

8. The known Oriental and Himalayan SIRICIDAE are listed and discussed. *Urocerus multifasciatus*, Takeuchi, and *Eriotremex formosanus*, Matsumura, are mentioned as two species originally described from Formosa but shown also to occur on the mainland. *Urocerus niger*, sp. nov., is described from the Himalayan region, and the name *Eriotremex malayanus*, sp. nov., is given to a form described without a name by Forsius from Malaya.

9. Several errors in previous work on SIRICIDAE are corrected.

References.

- BENSON, R. B. (1938). Some more new or little known British sawflies (Hymenoptera Symphyta) III.—Ent. mon. Mag., **74**, pp. 255-257.
 BRADLEY, J. C. (1913). The Siricidae of North America.—J. Ent. Zool., **5**, no. 1, pp. 1-35, figs. 1-39.
 ———. (1934). A new species of *Xeris* (Hymenoptera Siricidae) from the Himalayas. —Rec. Indian Mus., **36**, p. 145.

- CAMERON, P. (1908). A new species of *Tremex* from Borneo.—Entomologist, **41**, pp. 33-34.
- COCKERELL, T. D. A. (1921). Some British fossil insects.—Canad. Ent., **53**, pp. 22-23, figs. 26-27.
- CONDE, O. (1935). Oryssioidea et Tenthredinoidea collecta in Ussuri et Sachalin ab N. Delle.—Notul. ent., **14**, pp. 67-87.
- ENSLIN, E. (1912-18). Die Tenthredinoidea Mitteleuropas, 1-7.—Dtsch. ent. Z., Beih., 1912-1917.
- EVANS, W. (1922). Notes on the woodwasps (*Sirex*) occurring in Scotland with special reference to their present-day distribution.—Scot. Nat., 1922, pp. 175-189.
- FORSIUS, R. (1934). Notes on a collection of Malaysian Tenthredinoidea (Hym.).—Bull. Raffles Mus., **5**, no. 8, pp. 169-193.
- FRANCKE-GROSMANN, H. (1939). Ueber das Zusammenleben von Holzwespen (Siricinae) mit Pilzen.—Z. angew. Ent., **25**, no. 4, pp. 647-680, 18 figs.
- GHIGI, H. (1909). Sopra una nuova specie di Siricide delle Azore.—Boll. Soc. ent. ital., **40** (1908) pp. 163-170.
- GUIGLIA, D. (1937). Alcune osservazioni intorno *Tremex hyalinatus* Mocsáry (Hymen. Phytophaga).—Ann. Mus. Stor. nat. Genova, **59**, pp. 433-437, pl. xv.
- GUSSAKOVSKIĬ, V. V. (1935). Faune de l'URSS, (N. S.) no. 1. Insectes Hyménoptères. T. II, vol. 1 Chalastogastra, Pt. 1.
- HEDICKE, H. (1938). Hymenopterorum Catalogus, part 6, Siricidae.
- KONOW, F. N. (1905). Syst. Zusammenst. Chalastog., pp. 316-352.
- KOORNNEEF, J. (1935). *Paururus sucineiceps* Knf. 1935 ♀.—Tijdschr. Ent., **78** (Verslag) pp. xix-xx.
- LANGE, C. F. (1909). Beschreibung einer neuen Holzwespe aus Deutsch-Neuguinea (Hym.).—Dtsch. ent. Z., 1909, p. 210.
- MARTYNOV, A. (1937). Liassic insects from Shurab and Kisyl-Kiya.—Trav. Inst. Paléontol., **7**, p. 142, fig. 20 (p. 42).
- MATSUMURA, S. (1930). The illustrated thousand insects of Japan.—**2** (Hymenoptera).
- PECK, O. (1937). The males of *Urocerus albicornis* F. and *U. flavicornis* F. (Hymenoptera: Siricidae).—Canad. Ent., **69**, pp. 275-276.
- ROEBUCK, W. D. (1906). *Xeris spectrum* L. at Leeds: an addition to the British list of Hymenoptera.—Naturalist, 1906, p. 223.
- ROHWER, S. A. (1910). Japanese sawflies in the collection of the United States National Museum.—Proc. U. S. nat. Mus., **39**, pp. 99-120.
- ROSS, H. H. (1936). The ancestry and wing-venation of the Hymenoptera.—Ann. ent. Soc. Amer., **29**, no. 1, pp. 99-111, figs. 1-35.
- SAUNT, J. W. (1925). Notes on collecting, etc.—Ent. Rec., **97**, p. 94.
- SEMENOV-TIAN-SHANSKIĬ, A. (1921). Praecursoriae Siricidarum novorum diagnoses (Hymenoptera).—Rev. russe Ent., **17** (1917) pp. 81-95.
- SONAN, J. (1938). Siricidae of Formosa.—Trans. nat. H. Soc. Formosa, **28** no. 175, pp. 88-94, figs. 1-5.
- STEPHENS, J. F. (1835). Illustrations of British Ent., VIII. Uroceridae, pp. 111-116.

- TAKEUCHI, K. (1938). A systematic study of the suborder Symphyta (Hymenoptera) of the Japanese Empire (1).—*Tenthredo*, **2**, no. 2, pp. 187–195, fig. 4.
- TANSLEY, G. (1939). *The British Islands and their vegetation*. Cambridge.
- TILLYARD, R. J. (1927). The ancestry of the order Hymenoptera.—*Trans. ent. Soc. Lond.*, **75**, pp. 307–318, figs. 1–7, pl. XXVI.
- WATERSTON, J. (1928). In CHRYSTAL, R. N. *The Sirex wood wasps and their importance in Forestry*.—*Bull. ent. Res.*, **19**, pp. 219–241.
- WESTWOOD, J. O. (1874). *Thesaurus entomologicus Oxoniensis*. Oxford.
-

A SYNOPSIS OF THE AFRICAN SPECIES OF *METEORUS* (HYM., BRACONIDAE).

By G. E. J. NIXON, B.A.

Imperial Institute of Entomology.

This short review is incomplete in so far as it deals only with the material received by the Imperial Institute of Entomology for identification and that which is contained in the collections of the British Museum. A list of the species unknown to me is given at the end of the paper.

Nine new species and one new variety are described.

SUBFAMILY METEORINAE.

Genus *Meteorus*, Haliday.

With the exception of *nereus*, sp. n., which differs from all the other forms on venational characters, the African species seem to be very much alike in regard to their external anatomy. Both of the two well-known sections of the genus are represented—those with tracheal grooves on the petiole and those without them. It is probable that the African members of the second section could be divided, on biological grounds, into two groups, in one of which the parasite is gregarious (*neavei*, Brues) and the other in which it is solitary (*testaceus*, Szépligeti). The evidence for a parallel separation on the structural characters of the adults, however, appears so far to be slender.

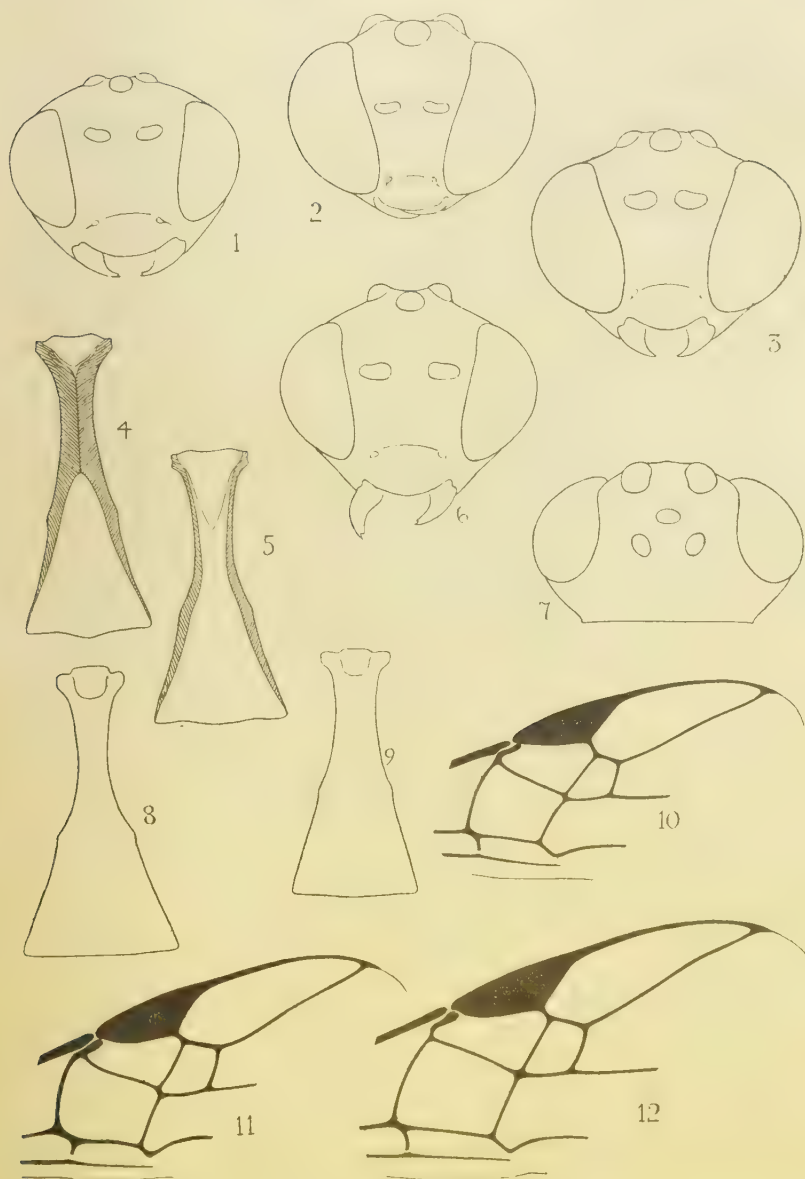
All the species to be dealt with have the following characters in common :—

Mandibles always of the form shown in fig. 6. Malar space at most a trifle longer than the basal width of the mandible. Eyes always large, convergent on the face, often strongly so. Nervulus always postfureal; radial cell of the hind wing never widened to apex.

Key to the Species (♀♀).

1. Petiole with tracheal grooves; ventral margins of the petiole not meeting along the middle line (fig. 5).....2
 Petiole without tracheal grooves; ventral margins of the petiole meeting and fused along the middle line (fig. 4).....6
2. 1st discoidal cell not stalked above nor even angled here; the abscissa of the discoideus between the basalis and the nervulus thickened and much more deeply pigmented than most of the rest of the venation.....*nereus*, sp. n.
 1st discoidal cell with a short stalk or at least angled here; the abscissa of the discoideus between the basalis and nervulus not noticeably thickened and not much more deeply pigmented than the rest of the venation.....3
3. Face between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets hardly $1\frac{1}{4}$ times as high as wide; eyes only weakly convergent below; ocell-ocular line not less than the longer diameter of a posterior ocellus.....*clytes*, sp. n.
 Face thus measured at least $1\frac{1}{2}$ times as high as wide; eyes strongly convergent below; ocell-ocular line clearly shorter than the longer diameter of a posterior ocellus 4

4. Postpetiole almost smooth, its striation subeffaced.....*croce*, sp. n.
Postpetiole with strong, smooth striation.....5
5. Ocell-ocular line more than half the longer diameter of a posterior ocellus.....
laphygmarum, Brues
Ocell-ocular line less than half the longer diameter of a posterior ocellus.....
ate, sp. n.
6. Middle lobe of the mesonotum on the whole dull and closely rugose.....7
Middle lobe of the mesonotum on the whole strongly shining, its sculpture subeffaced and superficial.....12
7. Face between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets much higher than wide; eyes large and strongly convergent below; malar space about half as long as the basal width of the mandible.....8
Face thus measured not much higher than wide, the eyes much less convergent below; malar space about equal to the basal width of the mandible.....9
8. Colour uniformly pale fulvous, the abdomen beyond tergite 1 not darker than the postpetiole.....*lipsis*, sp. n.
Colour pale brownish testaceous, the abdomen beyond tergite 1 darker than the contrasting pale postpetiole.....*lipsis*, var. ?
9. Upper-side of the body predominantly brown to the unaided eye.....
komensis, Wilkinson
Upper-side of the body predominantly pale, either fulvous red or fulvous yellow.....10
10. Ocell-ocular line about equal to the longer diameter of a posterior ocellus; postpetiole almost smooth, its striation subeffaced.....*triptus*, sp. n.
Ocell-ocular line at least $1\frac{3}{4}$ as long as the longer diameter of a posterior ocellus; postpetiole strongly striated.....11
11. Antenna with 30-32 segments; pale fulvous with very pale stigma.....
neavei, Brues
Antenna with 26-27 segments; bright brownish red with blackish stigma.....
tydeus, sp. n.
12. Tricoloured species, the thorax dull red, most of the abdomen blackish with the petiole, apex of the postpetiole and base of tergite (2+3) whitish.....
margaroniae, Wilkinson
Species not tricoloured.....13
13. Face between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets $1\frac{1}{2}$ times as high as wide.....14
Face thus measured only a trifle higher than wide.....15
14. Abdomen beyond the 1st tergite with two darks spots or clouds on each side...
trilineatus, Cameron
Abdomen beyond the 1st tergite entirely pale fulvous.....*testaceus*, Szépligeti
15. Mesonotum entirely fulvous; postpetiole more or less smooth along the middle line and with subobsolescent convergent striation on each side of the middle line.....
luodice, sp. n.
Mesonotum marked with three large blackish patches; postpetiole evenly striated.....*lal*, sp. n.



Figs. 1-12. 1. *Meteorus neavei*, Brues, head (from in front) ♀; 2. *M. ate*, sp. n., head (from in front) ♀; 3. *M. laodice*, sp. n., head (from in front) ♀; 4. *M. trilineatus*, Cam., tergite 1 (ventral); 5. *M. ate*, sp. n., tergite 1 (ventral); 6. *M. trilineatus*, Cam., head (from in front) ♀; 7. *M. trilineatus*, Cam., head (from above) ♀; 8. *M. tydeus*, sp. n., tergite 1 (dorsal); 9. *M. neavei*, Brues, tergite 1 (dorsal); 10. *M. neavei*, Brues, part of forewing, ♀; 11. *M. nereus*, sp. n., part of forewing, ♀; 12. *M. trilineatus*, Cam., part of forewing, ♀.

Meteorus trilineatus, Cameron.

1905, Rec. Albany Mus., **1**, p. 242.

♀. A predominantly tawny coloured species with the upperside marked with darker colouring as follows: a broad band along the upper margin of the sides of the pronotum, one on each lateral lobe of the mesonotum and a large patch on each side of the propodeum, brownish; frequently the middle lobe of the mesonotum shows two broad, parallel bands which almost touch but are rarely as dark as those of the lateral lobes; the patches on the propodeum frequently show a tapering prolongation which reaches as far as the insertion of the abdomen. Petiole pale; postpetiole brownish; tergite (2-3) and four with a brown spot or patch against lateral margin; those on four may be enlarged and confluent. Hind tibiae infuscated virtually throughout; at most the narrowed basal portion is paler. Stigma pale yellowish with a faintly darker border. Flagellum usually evenly brown but sometimes tawny towards base.

Head from above and in front as in figs. 6 & 7. Malar space equal to the basal width of the mandible. Face between a line joining the lower margin of the antennal sockets and the apex of the clypeus very slightly higher than wide, 22:19; convex and in a lateral view of the head projecting very obviously beyond the level of the eyes; its sculpture consisting of faint, transverse striation. OOL to the longer diameter of a posterior ocellus as 7:5. Antenna with 30-33 segments. *Thorax*: Mesonotum for the most part dull, rugose all over; notaulices not impressed, their course obscured by the surrounding rugosities. Propodeum closely and, on the whole, evenly reticulate all over. Mesopleural furrow reticulate-rugose, the area of rugosity large and wide; area above it shining, somewhat indistinctly punctate. Recurrens interstitial but occasionally received clearly into the 1st cubital cell; 2nd abscissa of the radius from $1\frac{3}{4}$ to $2\frac{1}{2}$ times as long as the 1st; nervulus postfurcal by a distance equal to about $\frac{2}{3}$ its own length (fig. 12). Outspur of the hind tibia only a little shorter than the inner one and not strikingly thickened. *Postpetiole* covered with fine even longitudinal striation. Ovipositor sheaths about as long as the hind tarsus.

♂. Like the female except for the usual sexual differences.

Length, ♂♀, 5 mm.

CAPE PROVINCE: Katberg, x.1932-ii.1933, 10 ♀♀, 5 ♂♂; Somerset East, x.1930-i.1931, 4 ♀♀, 3 ♂♂ (*R. E. Turner*). NATAL: Weenen, 1 ♂, 1 ♀ (*H. P. Thomasset*). The type female was taken at Grahamstown, Cape Province.

This is certainly *trilineatus*, sensu Brues, for the male determined by him as this species and recorded in 1926, is in the British Museum. I am accordingly accepting his interpretation until such time as Cameron's type can be examined.

Meteorus testaceus, Szépligeti.

1914, Mitt. zool. Mus. Berlin, **7**, p. 228.

M. testaceus, Szép. Brues, 1926, Proc. Amer. Acad. Arts Sci., **61**, p. 295.

The female believed to be Szépligeti's species by Brues and recorded by him as such is in the British Museum. For the present I am accepting Brues's interpretation.

M. testaceus is extremely close in structure to *trilineatus* and I am not absolutely sure that the two insects may not be forms of the same species. *M. testaceus* differs from Cameron's species as follows:—

♀. Entirely pale fulvous to the unaided eye; there is sometimes a broad, faint band of infuscation on each lateral lobe of the mesonotum, a dark cloud on each side of the propodeum and a variable amount of infuscation on the postpetiole. The stigma is faintly yellowish. The flagellum is pale fulvous throughout.

Ocelli slightly larger, the posterior pair closer to the eye-margin, OOL being to the longer diameter of a posterior ocellus as 12 : 11.

CAPE PROVINCE : Mossel Bay, 7 ♀♀, 3 ♂♂ : Ceres, ii, iii.1925, 2 ♀♀ (*R. E. Turner*) ; Kluitjes Kraal, x.1929, 4 ♀♀, bred from *Laphygma exigua*, Hb. (*Forester*). NATAL : Kloof, viii.1926, 2 ♀♀, 1 ♂ (*R. E. Turner*). UGANDA : Kampala, 27.vii.1921, 1 ♀ (det. as *testaceus* by Brues) (*H. Hargreaves*).

It is necessary to emphasise that the palest forms of this species are exactly like *laphygmarum*, Brues, in colour. Brues's species, however, has well developed tracheal grooves, among other structural differences. Both insects have been bred from the same host, *Laphygma exigua*, Hb.

***Meteorus lal*, sp. n.**

♀. Very closely related to the *trilineatus-testaceus* complex and differing from *trilineatus* as follows :—

Middle lobe of the mesonotum with a single broad brown band which is undivided and as dark as those on the lateral lobes ; except at the sides, the propodeum is dark brown all over. Tergite (2-3) with a large whitish yellow patch at base and a smaller, ill defined cloud of much the same colour in the middle ; in *trilineatus*, the pale parts of tergite (2-3) are more or less pale honey yellow. Altogether the pale areas of the body are less tawny than in *trilineatus* and more whitish yellow to the naked eye. Stigma darker, evenly brownish.

Eyes larger, more convergent on the face, the latter much higher than wide, 21 : 13. Malar space a trifle shorter. OOL equal to the longer diameter of a posterior ocellus. Darkened areas of the mesonotum more shining, less closely rugose and showing some indefinite punctuation. Recurrens received into the extreme base of the 2nd cubital cell ; 2nd cubital cell more contracted above.

CAPE PROVINCE : Mossel Bay, i.1922, 1 ♀ (*R. E. Turner*).

Type in the British Museum.

The larger, more convergent, eyes of this species certainly provide the most reliable criterion for separating it from *trilineatus*.

***Meteorus laodice*, sp. n.**

♀. Closely allied to the three preceding species and differing from *trilineatus* as follows :—

Pale fulvous throughout.

Head, seen from above, slightly more narrowed towards the occipital margin. Eyes larger, more convergent on the face, much as in *lal*, sp. n. (fig. 3) but the face, in a front view, is slightly less transverse than in this species. Ocelli larger, more prominently raised ; OOL a little less than the longer diameter of a posterior ocellus, 5 : 6. Face flattened and in a lateral view of the head not projecting beyond the level of the eyes. Antenna with 29 segments. Lateral lobes of the mesonotum more shining and less rugose. Propodeum slightly more closely and evenly reticulate. Recurrens received into the extreme base of the 2nd cubital cell ; radial cell slightly shorter and hence appearing a little wider (*cf.* fig. 12) ; 2nd discoidal cell a little shorter. Mesopleura less rugose below, its convex part showing a greater extent of shining surface. *Postpetiole* almost smooth along the middle line, its striation sub-effaced and at least at about middle of segment strongly convergent towards middle line.

S.W. AFRICA : Aus, 8-30.xi.1929, 1 ♀ (*R. E. Turner*).

Type in the British Museum.

Resembling *lal* in having large eyes, *laudice* differs from that species in having the face flatter, the radial cell shorter, the postpetiole differently sculptured and in being differently coloured *inter alia*.

Meteorus margaroniae, Wilkinson.

1927, Bull. ent. Res., **18**, p. 42.

A rather dark, tricoloured species to the unaided eye.

♂♀. Head yellowish brown with a dark patch on frons and ocellar region; posterior declivous part of the vertex also darkened. Thorax evenly dingy red to the naked eye. Petiole whitish yellow; postpetiole darkened except for a pale posterior margin; in two males the 1st tergite is pale throughout; rest of the abdomen blackish but whitish yellow along the basal margin of tergite (2+3); in the two males with the pale 1st tergite, tergite (2+3) shows a large pale patch, constricted in the middle, on basal half. Stigma evenly dark brown throughout.

♀. Face and clypeus strongly shining, smooth-looking, with at most some vague indefinite punctation. Eyes rather strongly convergent below; the face, measured between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets, nearly twice as high as wide, 9:5; further, the face is almost flat and projects only very slightly beyond the level of the eyes when the head is seen from the side. OOL equal to the longer diameter of a posterior ocellus. Antenna with 31-34 segments (4 ♀♀); flagellum slender, all the segments longer than wide. Malar space from $\frac{1}{3}$ to $\frac{1}{2}$ as long as the basal width of the mandible. Mesonotum on the whole dull and strongly rugose; lateral lobes more shining than elsewhere, indefinitely punctate to punctate-rugose; middle lobe with an indistinct longitudinal keel, often indicated only on anterior half; notaulices not impressed, their course marked by a band of coarse rugosity. Mesopleura very coarsely rugose below, the raised central part irregularly punctate. Inner spur of the hind tibia about $1\frac{2}{3}$ times as long as the outer one, which is considerably thickened. Recurrens usually received into the extreme base of the 2nd cubital cell but sometimes interstitial; 1st abscissa of the radius about $\frac{2}{3}$ as long as the 2nd; 2nd cubital cell clearly a little contracted above. Postpetiole with strong striation which tends to be obliquely convergent towards the middle line. Ovipositor sheaths fully as long as the hind tibia.

♂. Like the female but the eyes less convergent below and the malar space a little longer.

Length, ♂ ♀, 5.5-5 mm.

CAPE PROVINCE: East London, ii.1923, 4 ♀♀, 2 ♂♂, type series, bred from larva of the Pyralid, *Margaronia dimorpha*, Janse; Port St. John, 3 ♀♀, 1 ♂ (R. E. Turner). ZULULAND: Eshowe, 1 ♂ (R. E. Turner).

Meteorus neavei, Brues.

1926, Proc. Amer. Acad. Arts Sci., **61**, p. 297.

♀. A pale yellowish species with the postpetiole sometimes a little darkened and tergite (2+3) sometimes with two pairs of faintly darker blotches. Stigma evenly brown. Flagellum brown throughout. Hind tibiae and hind tarsi brownish.

Head from in front as in fig. 1. Eyes not strongly convergent below, the face between the apex of the clypeus and a line joining the lower margin of the antennal sockets not much higher than wide, 21:17; face with traces of transverse striation. Posterior ocelli separated from each other by about $1\frac{1}{2}$ times their diameter; OOL exactly twice as long as the greater diameter of a posterior ocellus. Malar space about equal to the basal width of the mandible. Antenna with 30-32 segments. Mesonotum with a large area of rugose-reticulation posteriorly, its lobes shining, with subfaced rugose-punctuation, smooth-looking; notaulices not impressed, their

course marked by a narrow line of rugosity. Propodeum with very irregular, delicate reticulation. Mesopleura strongly rugose below. Outer spur of the hind tibia only a little shorter than the inner one. Recurrens received into the extreme base of the 2nd cubital cell (fig. 10). *Postpetiole* strongly striated, the ridges parallel and more or less straight; tergite 1 is almost evenly widened from base to apex, the petiole itself being short and not much constricted (fig. 9).

♂. Like the female except that the flagellum is yellow throughout, this colour difference is striking and noticeable to the naked eye and could be regarded as a secondary sexual character. Hind tibiae and tarsi also yellow throughout.

Length, ♂ ♀, 4 mm.

E. AFRICA: Nyasaland, Mlanje (S. A. Neave).

A gregarious parasite, the larvae of which on leaving the host form a remarkable pendant communal cocoon. This is oval in shape, about 20 by 10 millimetres in size, dark brown in colour and has a closely woven surface, through which, as short points, the ends of the individual cocoons protrude.

Of the large series now in the British Museum only seven specimens were originally sent to Brues for description. Nor did he see the cocoon.

The important characters of this species are the distance between the eyes on the face and the shining, almost smooth lobes of the mesonotum.

Meteorus lipsis, sp. n.

Differs from *neavei* as follows:—

Flagellum of the female as well as that of the male, yellow more or less throughout. Abdomen beyond tergite 1 without darker blotches. Head somewhat brownish and contrasting with the pale fulvous body.

♀. Eyes much larger and more convergent below. Face between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets, about $1\frac{1}{2}$ times as high as wide, 22 : 15. Distance between the posterior ocelli equal to the longer diameter of one of them; OOL equal to the longer diameter of a posterior ocellus. Antenna with 28-29 segments. Malar space about half as long as the basal width of the mandible. Middle lobe of the mesonotum slightly less shining. Petiole narrower, more constricted in the middle, the spiracles more prominent.

GOLD COAST: Agwasi, 26.viii.1940, 6 ♀♀, 4 ♂♂, one ♀ the type, bred from larva of *Parallelia pudica*, Möschl., on *Bandeiraea simplicifolia* (H. E. Box).

Type in the British Museum.

The species is presumably gregarious.

Meteorus lipsis, sp. n., var. A.

I have examined two series of specimens, identical in all respects, which may possibly represent a colour form of *lipsis*, but as no differences in structure appear to be present, I am reluctant to regard the insect as a distinct species. The colour differences are as follows:—

♂♀. Pale brownish testaceous to the unaided eye with the abdomen beyond tergite 1 brown and contrasting sharply with the pale, almost whitish yellow, post-petiole.

The striations of the postpetiole tend to converge a little more towards the middle line than in *lipsis*.

SIERRA LEONE: Njala, vi.1930, 4 ♀♀, 1 ♂, labelled "ex caterpillar" (E. Hargreaves). GOLD COAST: Dodowah, iii.1937, 4 ♀♀, bred from *Achaea* sp. (G. S. Cotterell).

A gregarious parasite. The first mentioned series is accompanied by 11 cocoons hanging loosely together from a silken stalk of some two inches in length. The cocoons themselves are separately attached to the main cord.

***Meteorus komensis*, Wilkinson.**

1927, Bull. ent. Res., **18**, p. 44.

Differs from *neavei* as follows :—

♀. A dark brown species to the naked eye with the underside paler. *Head* pale brown with a dark cloud which envelopes the ocellar triangle and extends down over the posterior declivous part of the vertex. *Thorax* dark brown with the lateral and ventral surface and the scutellar shield proper, paler. Entire dorsal surface of the abdomen, hind tibiae and tarsi and the stigma, all dark brown.

Eyes rather small, hardly convergent below : face between the apex of the clypeus and a line joining the lower margin of the antennal insertions exactly as high as wide. Malar space a trifle longer. Nervulus a little more widely postfurcal : 2nd cubital cell more contracted above (cf. fig. 10).

UGANDA : Kome Island, Lake Victoria.

Structurally this species is so close to *neavei* that I am not altogether satisfied that the two species are distinct. The chief points of similarity lie in the size of the eye and the corresponding width of the face and also in the position of the ocelli.

***Meteorus triptus*, sp. n.**

Here is a species closely related to the *neavei-komensis* complex, having the same broad face. It may be compared with *neavei* as follows.

♀. Abdomen pale throughout. Stigma like the rest of the venation, very pale yellowish. Hind tibiae and tarsi yellow.

Face a little more evenly convex, its sculpture a little finer. Posterior ocelli further apart, the distance between them being about twice the longer diameter of one of them ; OOL only a trifle longer than the longer diameter of an ocellus, 10 : 9. Antenna with 27 segments (2 ♀♀). *Mesonotum* with a smaller area of rugosity posteriorly and the sculpture within this area finer. Propodeum more convex in appearance, less hollowed out posteriorly, more shining and with more delicate reticulation ; there is a fine medial carina present and the surface on each side of it is nearly smooth. Second abscissa of the radius a little longer in proportion to the 1st. Mesopleura considerably less rugose. *Postpetiole* almost smooth, showing only a trace of obsolescent striation.

Length, about 3.3 mm., without ovipositor.

S.W. AFRICA : Aus, xii.1929, 1 ♀, i.1930, 1 ♀, the type (R. E. Turner). CAPE PROVINCE : Mossel Bay, 15.iii–20.iv.1932, 1 ♀ (R. E. Turner).

Type in the British Museum.

From *komensis*, which has an equally broad face, this species can be separated at once by the lack of definite sculpture on the 1st tergite as well as by colour and other details.

***Meteorus tydeus*, sp. n.**

Closely allied to *neavei*, which it resembles in having the eyes only very feebly convergent on the face. It may be compared with *neavei* as follows :—

♂♂. A rather distinctive species on colour alone, being predominantly of a bright brownish red tint : in the ♀, the ocellar triangle is blackish and there is a dark patch at the posterior end of each lateral lobe of the mesonotum ; in some males these dark

mesonotal patches are continued forwards as broad bands along the lobes and sometimes in the ♂ the middle lobe is also blackened. Flagellum black in both sexes. Hind tibiae reddish but the hind tarsi blackish. Stigma blackish.

♀. Antenna with 26-27 segments. First tergite less evenly widened to apex, the petiole narrower, more constricted at middle and the spiracles more prominent (fig. 8). OOL slightly shorter.

CAPE PROVINCE : Mossel Bay, iv-xii.1921, 4 ♀♀, 10 ♂♂, (one ♀, the type, 5-31.vii.1921) (*R. E. Turner*).

Type in the British Museum.

Species with tracheal Grooves present on Petiole.

***Meteorus laphygmarum*, Brues.**

1926, Proc. Amer. Acad. Arts Sci., **61**, p. 296.

M. fasciatus, Brues, 1926, Proc. Amer. Acad. Arts Sci., **61**, p. 296, ♂.

♂♀. Entirely pale fulvous with the postpetiole sometimes infuscated on each side. Stigma pale brownish, paler along its outer border. Antenna in the ♀ yellow at base, in the ♂ almost entirely yellowish.

♀. Face measured between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets nearly $1\frac{1}{2}$ times as high as wide, 21 : 16. Face weakly convex but in a lateral view of the head projecting strongly beyond the level of the eyes ; its sculpture consists of traces of transverse striation. Ocelli large and prominent, the distance between the posterior pair equal to the longer diameter of one of them ; OOL $\frac{2}{3}$ as long as the longer diameter of a posterior ocellus. Eyes rather strongly convergent towards the face. Malar space a trifle shorter than the basal width of the mandible. Antenna with 29 segments (5 ♀♀). *Mesonotum* on the whole dull, roughly sculptured all over ; middle lobe with a fairly well developed longitudinal keel ; notaulices not impressed their course indicated by a line of coarser sculpture. Propodeum irregularly and rather coarsely reticulated. Recurrens received into the base of the 2nd cubital cell ; 1st abscissa of the radius from $\frac{2}{3}$ to $\frac{3}{4}$ as long as the 2nd ; 2nd cubital cell distinctly contracted above. Lower impressed part of the mesopleura coarsely rugose-reticulate ; the shining surface above it feebly punctate. Outer spur of the hind tibia about $\frac{3}{4}$ as long as the inner one. *Postpetiole* evenly striated. Ovipositor sheaths about as long as the hind tibia.

♂. Like the female but the eyes less convergent on the face.

Length, ♂♀, ca. 4.6 mm.

BRITISH SUDAN : Khartoum, 22.ii.1927, 5 ♀♀, 2 ♂♂, bred from *Heliothis obsoleta*, F. (*H. W. Bedford*) ; Shambat, ii.1927, 4 ♀♀, 2 ♂♂, bred from *H. obsoleta* (*H. W. Bedford*) ; Wad Medani, 2 ♀♀, 2 ♂♂, bred from *H. obsoleta* (*H. B. Johnston*). RHODESIA : Salisbury, type ♀, in British Museum, bred from *Laphygma exigua*, Hb. TRANSVAAL : Tzaneen, iv.1937, 2 ♀♀, bred from *Laphygma exempta*, Wlk.

Brues's paratype of *fasciatus*, which is in the British Museum and which I am confident is identical with *laphygmarum*, has, in addition to the darkened postpetiole, the more apical part of the abdomen beyond it infuscated ; the posterior polished marginal band of the scutellum is also darkened.

It should be noted that *Meteorus testaceus*, Szép., has also been bred from *Laphygma exigua* and is superficially very like *laphygmarum* but differs from it chiefly in not having tracheal grooves on the petiole.

Meteorus ate, sp. n.

A very distinctive species with strongly convergent eyes; it may be compared with *laphygmarum* as follows:—

♀. Predominantly dull brownish fulvous to the naked eye. There seems to be a considerable degree of infuscation on the thorax; the lateral lobes are distinctly darker and redder than the middle lobe; in darkest examples they may each show a broad blackish band and in such examples there is usually a dark patch on the middle lobe; in two females, the sides of the thorax are much infuscated and the propodeum is almost black. Stigma a little darker than in *laphygmarum*.

♀. Head from in front as in figure 2. Eyes very large and strongly convergent below, the face including the clypeus almost $1\frac{3}{4}$ times as high as wide, 19:11. Malar space very short, hardly half as long as the basal width of the mandible. Face, in a lateral view of the head, virtually not projecting beyond the level of the eye at least above the clypeus, faintly roughened. Ocelli large and prominent, the distance between the posterior pair equal to about the diameter of one of them; OOL only about $\frac{2}{3}$ as long as the greater diameter of a posterior ocellus. Antenna with 24–27 segments. Mesonotum sloping more steeply to the pronotum, its sculpture on the whole a little finer, the lateral lobes sometimes decidedly more shining than the middle lobe; no trace of a medial keel on the middle lobe.

♂. Like the female but the eyes less convergent.

Length: ♂♀, 3.8 mm.

S.W. AFRICA: Aus, xi.1929–i.1930, 14 ♀♀ (type ♀, i.1930), 2 ♂♂ (R. E. Turner).

Type in the British Museum.

This species is chiefly characterised by the strongly convergent eyes, the nearness of the posterior ocelli to the eye margin and the short antennae.

Meteorus croce, sp. n.

♀. Differs from *laphygmarum* as follows:—

A predominantly pale fulvous species with the following parts embrowned:—the mesopleura beneath the wing insertions, the sides of the scutellum, the postscutellum and the postpetiole and the outer side of the scape.

Antenna with 30 segments (1♀). Face including the clypeus $1\frac{3}{4}$ times as high as wide, 7:4, slightly less convex above the clypeus but not as flat as in *ate*. Malar space about $\frac{2}{3}$ as long as the basal width of the mandible. Ocelli slightly less prominent, the hind pair separated from the eye-margin by about half their longer diameter. Mesonotum equally dull but its sculpture finer, much like that of *ate*. Propodeum slightly more regularly reticulated. Lower part of the mesopleura more finely sculptured. Postpetiole very shining and almost smooth, its striation subeffaced.

CAPE PROVINCE: Mossel Bay, ii.1922, 1 ♀ (R. E. Turner).

Type in the British Museum.

This species resembles *ate* in having the eyes very strongly convergent on the face but it differs from that species in that the posterior ocelli are less close to the eye-margin, the antenna is more slender with more segments and the postpetiole is nearly smooth.

Meteorus clytes, sp. n.

♀. A species closely related to *laphygmarum*, *croce* and *ate* but differing from all of them in having the eyes much less convergent. It may be compared with *laphygmarum* as follows:—

Postscutellar region and postpetiole faintly infuscated. Stigma brownish but paler broadly along the outer border. Hind tibiae towards apex, hind tarsi entirely, brownish.

Eyes only weakly convergent below, the face including the clypeus not much higher than wide, 19 : 16. Face gently convex and with traces of fine transverse striation. OOL slightly greater than the longer diameter of a posterior ocellus, 6 : 5 ; ocelli slightly less large and less prominent. Malar space as long as the basal width of the mandible. Antenna with 27 segments (2 ♀♀) ; the more apical segments of the flagellum slightly shorter and stouter than in *laphygmarum*. Sculpture of the mesonotum slightly finer, hardly distinguishable from that of *alc* and *croce* ; the mesonotum slopes more abruptly to the pronotum than in *laphygmarum* and in this respect the species resembles both *alc* and *croce* ; a longitudinal keel on the middle lobe of the mesonotum is faintly indicated.

CAPE PROVINCE : Mossel Bay, v.1921, 1 ♀, the type, 5 31.vii.1921, 1 ♀, 15.iii.20.iv.1922, 1 ♀ (*R. E. Turner*).

Type in the British Museum.

***Meteorus nereus*, sp. n.**

Although superficially very like *laphygmarum* and *testaceus* being of the same pale fulvous colour, this species is isolated and of particular interest in that the venation shows, for *Meteorus*, a marked divergence from the usual pattern.

♀. The lateral lobes of the mesonotum are slightly redder and more intense in colour than the middle lobe. Flagellum pale fulvous throughout. Stigma pale, almost dirty white with a faintly darker border ; discoideous, especially between the basalis and the nervulus strongly infuscated and contrasting with the rest of the venation.

Face between the apical margin of the clypeus and a line joining the lower margin of the antennal sockets, about $1\frac{1}{2}$ times as high as wide ; feebly convex, its sculpture consisting of broken transverse striation. Frons with strong transverse striation. Antenna with 34 segments ; flagellum slender, all its segments longer than wide. Posterior ocelli separated from each other by about their own diameter ; OOL hardly less than the longer diameter of a posterior ocellus. Posterior, declivous, part of the vertex irregularly striated.

Mesonotum strongly rugose-reticulate all over. Mesopleura strongly rugose below ; raised surface above also rugose but more finely. Propodeum coarsely reticulated. Outer spur of the hind tibia about $\frac{2}{3}$ as long as the inner one. Wings : 1st discoidal cell without a trace of a stalk above, its apex widely contiguous with the prostigma ; that part of the discoideus between the basalis and the nervulus markedly thickened ; 2nd cubital cell virtually parallel-sided (fig. 11). Postpetiole strongly striate, the striation curved inwards at the apex of the segment. Tergite (2 + 3) with traces of oblique striation which mid-basally is arranged in the form of a semicircle. Ovipositor sheaths about as long as the hind tarsus.

Length : about 5 mm.

GOLD COAST : British Togoland, Kpeve, 20.x.1931, 1 ♀ (*G. S. Cotterell*).

Type in the British Museum.

Species unknown to the Writer.

1. *Meteorus durbanensis*, Brues, 1926, Proc. Amer. Acad. Arts Sci., **61**, p. 294.
2. *Meteorus flavicornis*, Szépligeti, 1914, Mitt. zool. Mus. Berl., **7**, p. 228.
3. *Meteorus kleini*, Szépligeti, 1918, Beitr. Landf. Südwestafrikas, **1**, p. 191.
4. *Meteorus tricolor*, Szépligeti, 1913, Ann. Mus. Nat. Hung., **11**, p. 607.

References.

- BRUES, C. T. (1926). Studies on Ethiopian Braconidae, with a catalogue of the African species.—Proc. Amer. Acad. Arts Sci., **61**, pp. 205–436.
- MUESSEBECK, C. F. W. (1923). A revision of the North American Ichneumon-flies belonging to the genus *Meteorus* Haliday.—Proc. U. S. nat. Mus., **63**, pp. 1–44.
-

A SURVEY OF BRITISH SHEEP BLOWFLIES.

By J. MACLEOD, D.Sc., Ph.D.

Cooper Technical Bureau, Berkhamsted.

INTRODUCTION.

Blowfly myiasis of sheep has been recognised as an economic problem in this country for centuries, whereas in the other great sheep-raising countries, with their much younger sheep industries, the problem is of relatively recent growth. Yet, surprisingly, scientific investigation of the disease as it occurs in this country has lagged tardily, so that, when the serious epizootic of 1930-34 focussed attention on the problem, the only published investigational work was that of MacDougall (1904, 1909).

Shortly before MacDougall's work, the popular belief that the condition was due to the common blowflies of carrion—*Lucilia*, *Sarcophaga* and *Calliphora* species—had been challenged by Neumann (Fleming's translation, 1892), who drew attention to Portchinski's finding that infestation of wounds of living animals in Russia was generally due to *Wohlfahrtia magnifica*. Ritzema Bos (1891), on the other hand, found that in an outbreak of myiasis in Holland the fly concerned was *L. sericata*. Carpenter (1902) bred *L. sericata* from larvae taken from a sheep in Co. Wicklow, and Brown (1902) reported having bred out *L. caesar* from a case of sheep myiasis in west England. His description of a small fly with a metallic greenish abdomen—might equally well have referred to *L. sericata*.

MacDougall bred out 51 samples of larvae, obtained from living sheep in Scotland, England and Ireland; he showed that the fly concerned was *L. sericata*, except in six cases when *C. erythrocephala* occurred, either alone or mixed with *L. sericata*.

Between 1909 and 1933, much work in Australia, South Africa, and North America showed that in addition to *L. sericata* many other species of blowflies might be involved, either in the causation or aggravation of cutaneous myiasis—strike—of sheep. Nevertheless, no attempt was made to re-examine the problem in Britain, until 1928, when Maldwyn Davies began the fruitful series of investigations of the blowfly problem generally, which, after his death, was continued so brilliantly by his colleague Hobson, until his death in 1941. Davies examined 182 strikes from widely separated farms in North Wales and found that *L. sericata* was the species responsible in all but two cases, where *C. erythrocephala* was also present (Davies, 1934). Ratcliffe (reported by Ritchie, 1934) also failed to incriminate other than *L. sericata* in an investigation of cases in north-east Scotland.

The question of the cause of sheep strike in this country was, however, reopened by the publication in 1937 of the results of two independent investigations, *etc.*, that of Haddow and Thomson in south western Scotland, and my own in western Scotland, the Lothians and south-east England. Haddow and Thomson bred six species of fly in addition to *L. sericata* from larvae collected from strikes on living sheep. The most important of these so-called "secondary" species was *L. caesar*, and evidence was given to suggest that *Phormia terraenovae* was also a relatively common secondary species; *L. illustris* was found in a limited number of instances, while *C. erythrocephala*, *C. vomitoria*, and *Muscina pabulorum* occurred only rarely. I was able to confirm the incrimination of *P. terraenovae* as an important striking species in western Scotland, and also the occurrence of *L. caesar* in an appreciable proportion of strikes, both in Scotland and England; I submitted evidence for believing that these two species were primary flies.

The conflicting results of workers in different localities made it seem desirable that a reasonably comprehensive survey should be made of the species affecting sheep throughout the country, and at different seasons of the year. Arrangements were accordingly made for samples of larvae to be collected from cases of strike and sent to the laboratory for rearing and identification. Altogether 1,032 samples were sent in between 1938 and 1941. In addition, 232 samples were collected from the experimental flocks at the Cooper Field Research Station, at Little Gaddesden, Herts. These, with the cases examined by me in 1934-36, give a total of 1,386 samples from separate cases of strike; in 1,307 of these, the flies have been bred out and identified. Table I gives the distribution of the cases:—

TABLE I.

Country	1934-36	1938	1939	1940	1941	Total
Scotland	69	174	165	21	49	478
England		128	90	7	85	310
Wales			210			210
Ireland... ..			103			103
Experimental Farm ...	53	58	118	56		285

TABLE II.

Area	Samples			<i>L. seri-</i> <i>cata</i>		<i>L. caesar</i> type		<i>P. terrae-</i> <i>novae</i>		<i>Calliphora</i> spp.		Total Altern- atives
	Farms	Re- ceived	Iden- tified	Pure	Total	Pure	Total	Pure	Total	Pure	Total	
North-west Scotland	11	24	19	15	19		1		3			4
Outer Hebrides	6	12	11	11	11							
Western Scottish Highlands...	13	126	107	47	78	17	41	8	19	1	8	60
Central Scottish Highlands ...	12	34	33	21	30	1	5		6	2	2	12
North-eastern Lowlands	9	17	17	17	17							
Central Lowlands	21	138	133	103	125	2	19			5	9	30
Tweed Basin	15	86	81	78	81		2				1	3
Solway and Lake District	29	124	117	91	115		18		7	1	5	26
Pennines and Yorkshire	6	26	26	21	25		3		1	1	1	5
North Wales	36	149	145	124	137	6	19			2	2	21
South Wales	19	61	59	58	58	1	1					1
Central England	16	57	49	49	49							
Eastern Plains... ..	10	34	33	32	33						1	1
Southern England	7	40	39	36	39		3					3
South-west Peninsula... ..	8	70	65	64	65		1					1
Ireland	22	103	97	95	97		2					2
Field Station, Herts... ..		285	276	257	276		16				3	19

The investigation is by no means complete, but sufficient evidence has been accumulated to justify a provisional analysis of the results. It has been decided, therefore, because of wartime difficulties in prosecuting an investigation of this kind, to publish the work as it stands, in the hope that at some later date the survey may be satisfactorily completed.

METHODS.

Samples were in all cases taken from strikes on living sheep. Small tins were supplied containing sand-sawdust mixture in which the larvae could survive transmission by post. With the tins, which were numbered for reference, questionnaire forms were sent, on which full particulars of the host, locality and vegetation type for each case could be entered. Shepherds were asked to aim at one sample each week, and although this was not always possible, the response in many cases was excellent, several useful series of samples being received throughout the season.

The samples, on receipt, were sieved out from the sand mixture, and, if the larvae were not full-grown, they were placed with meat in a closed receptacle and kept in an incubator at 25 C. until development was complete. In the great majority of cases it was possible to dispense with further feeding. When pupation was complete the puparia were returned to the appropriate tins. The emerged imagos were left to die, and examined as opportunity arose during the winter months. Identifications were made with a low power binocular microscope; in doubtful cases, with male examples of *Lucilia*, the identification was checked by examination of the mounted genitalia.

REGIONAL SURVEYS.

For purposes of the survey the British Isles were divided into 16 regions. In view, however, of the distribution and the limited number of the samples received from Ireland, this island, which was originally regarded as forming three regions, has been treated as one. A short description of each region prefaces the detailed account of the investigational findings; the boundaries are also illustrated in fig. 1.

The results of the survey are summarised for the different regions in Table II, which gives the number of cases in which each species occurred, (a) in pure culture, and (b) either in pure culture or mixed with other species. The summarised results are shown graphically in the circle diagrams for each region (fig. 1), which represent the number of cases and the relative incidence of *L. caesar*, *Phormia*, and *Calliphora* spp. The two species, *L. caesar* and *L. illustris*, have been grouped together under the heading *L. caesar* type, and in the following text, the name *L. caesar* refers to *L. caesar* and/or *L. illustris*. Their separate distribution is discussed in a later section.

The term "alternative species," in preference to "secondary species," is used in the text, to refer to species other than *L. sericata*.

I. North-west Scotland.

The southern boundary of this region has been taken as the Loch Torridon-Strath Bran pass, dividing the harsher, more barren northern region of the north-west from the milder west and central highlands. The region consists, in the western part, of wet moor with a high proportion of bare rock outcrop. There is little wood, except fringing the sheltered seaboard glens, and the climate inland is severe. To the east, the vegetation improves in quality under a drier regime; woods become commoner, and the wet upland moors tend to be replaced by drier heather heaths. The N.E. and S.E. corners of this region are fertile agricultural areas.

The number of samples received from the region was disappointingly low. Six farms on the western seaboard, from Loch Inchart to Ullapool, contributed 13

samples but in four cases the larvae died and were not identified. *Phormia terraenovae* occurred in two of the remaining nine, in both instances on the south coast of Eddrachilis Bay. The cases occurred in late July and late August respectively. Incidentally, I have observed the puparia of this species in the wool of sheep carcasses in this same area.



Fig. 1. Showing the division of Britain into regions in relation to orography. The three circles illustrate the relative incidence of *L. caesar*, *P. terraenovae* and *Calliphora* spp. in that order. The black sector indicates the incidence of pure, and the hatched sector of mixed, infestations of the species. The area of the circles is in proportion to the total number of samples examined. The inset illustrates the results for the Research Station, on the Chiltern ridge.

Haddow (private communication) obtained three samples of larvae from Gairloch, in the second half of August. All three were *L. sericata*.

Five farms in Caithness, east Sutherland, and the Black Isle contributed 11 samples. *Phormia* occurred in a June sample, one of a series of four from a farm in the Black Isle, and *L. caesar* in one of two from a farm near Rogart, east Sutherland (early August).

II. The Outer Hebrides.

From this region, bleak, low, windswept and treeless, only 11 samples were obtained. These were sent in during June, July, August and September, from farms in Lewis and N. Uist. Only *L. sericata* was recovered, but in view of the limited number of samples, too much significance should not be attached to this finding.

III. The Western Scottish Highlands.

This region comprises the remaining western Isles and the deeply dissected seaboard of headland and loch which forms a western fringe to the main Highland mountain mass. The eastern boundary has been taken as a line from Loch Torridon down the western crest of the main mountain plateau, by Ben Nevis, the edge of the Rannoch moor, and Dalmally pass, to Loch Gail and the Clyde.

This is a region of high rainfall and mild winters, rank bracken and scrub in the deep glens and fringing the winding sea lochs, and moss and *Scirpus* on the water-sodden moors.

Table III shows the seasonal distribution of the different species for half-monthly intervals, in the given areas of this region.

TABLE III.

Area	Farms	No. of Samples	May	June	July	August	September
Skye ..	1*	14		3 Ls 2 Ls	1 Ls 1 Ls 1 Ls+Ptn+Lc 1 Lc 1 Lc	4 Ls+Lc	
Mull ..	2	18			1 Ls 4 Ls 1 Ls+Ptn 1 Ptn 3 Ptn 1 Ls+Lc	1 Ls 1 Ls	1 Ce 1 L 1 Lc+Ce 1 L 1 L 1 L
Morvern	2	31			3 Ls 1 Ls 1 Ls+Lc 1 Ls+Lc 2 Ls+Ptn 1 Lc 6 Ls 2 Ptn 1 Ls+Ce	2 Ls+Lc 5 Ls 1 Lc 2 Ls+Lc 1 Ptn	1 Ls 1 Ls 1 L 1 L
Lorne ..	4	32	2 Ls	Ls+Ptn Ls	5 Ls 2 Ls 1 Ls+Lc+Ptn 1 Ls+Lc 2 Lc 1 Ls+Lc+Ptn 1 Ls+Ce 1 Ls+Ce+Ptn 1 Ptn	3 Ls 3 Ls 1 Ls+Lc+Ptn 1 Ls+Lc	3 Ls 1 Ls 1 Ls+Lc+Ce 1 L
Claddich and Dalmally	4	12			2 Ls 1 Ls 1 Ls+Lc 1 Ls+Lc 1 Ls+Ptn 2 Lc 1 Lc 1 Lc+Ptn		1 Ls

* Farm in Watnish.

In this and subsequent tables in this section the abbreviations used are: -Ls = *L. sericata*, Lc = *L. caesar* type, Ptn = *P. terraenovae*, Ce = *C. erythrocephala*, Cv = *C. vomitoria*.

With regard to the remaining areas, Morison (1942) reports having found puparia of *P. terraenovae* in the wool of a sheep carcass at Dornie, Ross shire; Haddow and Thomson record *L. caesar* from Cowal, *L. caesar*, *C. erythrocephala* and *C. vomitoria* from Knapdale, *L. caesar* and *P. terraenovae* from Kintyre, and *L. caesar* and probably *P. terraenovae* from Arran. No records have been obtained for Jura, Islay or the smaller Islands.

IV. *The Central Scottish Highlands.*

This is the mountain region formed by the main Grampian plateau. To the south it is delimited by the Highland Boundary Fault, but to the N.E. there is no such limit, the lowland hills being so deeply penetrated by fertile valleys, and the coastal plain.

The region generally consists of mountain and moor, transected by narrow valleys, including the long slash of Glenmore. The climate is harsher than that of the western region, the valleys tend to be less sheltered, but there is an improvement of vegetation eastward with decreasing rainfall and consequent improvement of soil conditions.

The results for the different areas in this region are given in Table IV.

TABLE IV.

Area	Farms	Samples	June	July	August	September
Glenmore basin	3	8	1 Ls 1 Ls+Ptn	1 Ls 1 Ls+Lc 1 Cv	2 Ls	1 Ls
Badenoch	1	9	1 Ls 1 Ls+Ptn	2 Ls 1 Ls+Ptn	1 Ls 1 Ls	1 Ls 1 Cv
Eastern Foot Hills	2	5	1 Ls	2 Ls 1 Ls+Lc+Ptn	1 Ls	
Tay Basin	2	7	2 Ls 1 Ls+Lc	1 Ls	2 Ls 1 Ls+Lc	
Southwest	4	4		2 Ls+Lc 1 Lc		1 Ls

Of the three farms in the basin of the Great Glen one is on the southern shore of the Beaulieu Firth and possibly would be more appropriately included with the Black Isle farms. Of the five samples received from it, four were *L. sericata*, the fifth *C. cornuta*. *Phormia* occurred in the only sample received from a farm near Tomatin, and *L. caesar* in one of the two samples from near Fort Augustus. The Badenoch samples were from one farm near Kingussie.

The occurrence of *P. terraenovae* in the Aberdeen foothills (near Alford), has since been confirmed by Morison (1942). In a private communication he informs me that the species was recovered from cases in Glen Saugh, Kincardineshire, Glen Cat, Glen Tamar, Dunsicht, Alford and Glenkindie, Aberdeenshire. Haddow and Thomson record *L. caesar* from the North Esk, in this area.

The Tay basin is loosely used to indicate that area within the Central Highland region which borders on Strathmore, including the valleys running into the Strath—the upper Tay, Glen Shee and Glen Prosen. The samples obtained were from Bankfoot and Alyth, *L. caesar* occurring on both farms.

By the south-east area is meant the Trossachs, Balquhiddier, Loch Earn and Loch Tay. Only one sample each was received from Balquhiddier and Loch Tay and two from the Trossachs. The Balquhiddier sample was a pure *L. caesar* culture: both the Trossachs samples were *L. sericata* and *L. caesar* mixed. *Phormia* was not recovered in this area, but I have observed the species in the wool of sheep in Balquhiddier, and Morison reports it from strikes in Balquhiddier and Strathlyre (private communication).

V. *North-east Scotland.*

This lowland region comprises the rich agricultural lands of Buchan, the basin of the Don, and, to the north, the Laigh of Moray, with foothills and fertile valley

bottoms forming a fringe between these and the mass of the Central Highlands. The region is characterised by relatively low rainfall and high temperature, and a high standard of modern arable farming has developed. Cattle and pig farming are important, but sheep become predominant in the foothill areas flanking the Grampians.

Samples were recovered from farms near Lossiemouth, Old Muthros, Kincraig, Peterhead, and Cruden Bay. In all cases *L. sericata* was bred out. In addition, there are the results of Ratchine's investigation, details of which were not given, but which presumably referred to farms in Aberdeenshire; only *L. sericata* was obtained. MacDougall reports *C. erythrocephala* from Keith. One of Manson's *Plumaria* localities lies within this region, Dunocht. The infestation may have occurred on the Hill o' Fare, an isolated hill mass with all the characters of the more western Aberdeen hills.

VI. The Central Lowlands.

This is the lowland belt lying between the Highland Boundary Fault and the less well defined Caledonian fold which marks the northern escarpment of the Border Uplands. The lower limit runs from the coast south of Dunbar, by the edge of the Lammermuirs and Moorfoot Hills, across the Biggar Gap and through Glenbank, to the sea near Girvan, south of which the moors reach to the coast.

The region is principally arable or industrial lowland, but includes the series of volcanic hills fringing the Highland Fault—the Kilpatrick Hills, Campsie Fells, Ochil and Sidlaw Hills, and similarly fringing the southern Uplands, the Pentlands Hills and the hills of eastern Ayrshire. These form too for high concentrations of sheep, while cattle vie with sheep in the more intensely cultivated lowlands. The climate is generally speaking dry and sunny, especially in the east, with rather more rainfall and less sunshine in the western areas.

The great majority of the samples for this region have been received from the north-eastern part, north of the Clyde-Forth line. No samples have been received from the west or south-west. Table V gives the results.

TABLE V.

Area	Farms	No. of Samples	June	July	August	September
Mearns	4	19	1 Ls 2 Ls	2 Ls 6 Ls	3 Ls 2 Ls	1 Ls—Lc
Strathmore and Strathearn	2	22	1 Ls 2 Ls 1 Cv	2 Ls	4 Ls 5 Ls 3 Ls+Lc 1 Ce	3 Ls
Stirling	5	15	1 Ls 1 Ls+Lc	3 Ls 1 Ls+Lc 4 Ls+Lc	2 Ls	2 Ls 1 Ls—Lc
Fife	4	34	3 Ls 4 Ls 2 Ls+Lc	4 Ls 3 Ls	5 Ls 6 Ls 1 Ls+Lc	4 Ls 1 Ls 1 Ls+Lc
Lothians	6	42	3 Ls 3 Ls	1 Ls 2 Ls	7 Ls 6 Ls 1 Ls+Lc 1 Ls+Lc 1 Ls—Ce 1 Ce 2 Ce	7 Ls 1 Ls 1 Ls—Lc 2 Lc 2 Ls—Ce

The Mearns area—the lowland basin of the Esk—has been extended to include the Dundee plain. In only one sample was other than *L. sericata* obtained, from a farm near Kirriemuir, bordering the Central Highland region.

The Strathmore and Strathearn area continues west of the Mearns, along the flank of the Grampian Mountain escarpment. The area consists of fertile plains with the low Sidlaw hills flanking it to the east, and the Ochils to the south. To the north-west it is sheltered by the towering Grampian escarpment. The area is

thus a sheltered borderland between highland and lowland types, and it is not surprising that a higher proportion of alternative species occurs here than in the more purely lowland Mearns. The two instances of *Calliphora* infestation were from the same farm, in different years.

The Stirling area continues westward along the foothills of the Grampians. It includes the rich Carse of Forth, the low, favoured sheepwalks of the Campsie and Kilsyth hills, the plain of Strathblane and the Kilpatrick Hills. It thus resembles the previous area in its borderline character, and again we find a high proportion of alternative species. Five samples from a farm near Doune were all *L. sericata*; those from the remaining four farms, one near Stirling, the other three in Strathblane and the Campsie Fells, were in most cases mixed *L. sericata* and *L. caesar*.

The remaining samples for this region are grouped in two areas, Fife and the Lothians, flanking the Firth of Forth to north and south. Three samples from the Fife area yielded *L. caesar*, two out of a series of 17 from one farm near St. Andrews, the third from near Ladybank. The *Calliphora* record also comes from Ladybank. MacDougall also records this species from the area (Kinross). In the Lothians area the samples were received from farms both in the plains and on the Pentland foothills. An interesting feature is the unusually large proportion of *Calliphora* in the alternatives—more than half the total. They were obtained in pure culture in the Lowlands near S. Cobbinshaw, and both alone and mixed with *L. sericata* in the Pentland hills. In all cases the species was *C. erythrocephala*.

With regard to the remaining areas, Haddow and Thomson record, from the Fenwick Moors in North Ayrshire, *L. illustris*, *P. terraenovae*, and *Muscina pabulorum*, along with *L. sericata*. In the south, bordering the Southern Uplands in Lanark, they obtained a pure culture of *C. erythrocephala*. MacDougall also reports a pure culture of this species from Auchendruie, Ayrshire.

VII. *The Tweed Basin.*

This region consists of the Tweed basin and the great horseshoe of hills around it. It is limited on the north by the Lammermuirs and Moorfoots, on the west by the high hills round the head waters of the Clyde, and on the south by the South Tyne gap which divides the Cheviots from the Pennines. The boundary is taken as a line through the Sanquhar gap, across to Beattock, Langholm, Haltwhistle, and along the Tyne to Newcastle.

Broadly speaking, the region may be described as open upland, the slopes being gentle, and usually grass covered to the summits. Rock outcrop or scree is rare.

The rainfall is relatively low, and a considerable degree of mixed farming occurs, especially in the lower basin of the Tweed, but the region is primarily a sheep area and is indeed unique in the density of its sheep stocks.

Samples were received from the lower Tweed basin (2 farms), the Selkirk and Hawick basin (3 farms), the Lammermuirs (1 farm), the Upper Tweed, from the Biggar Gap to Innerleithen (4 farms), the Liddisdale and Esk area (1 farm), the Cheviot ridge (2 farms), the North Tyne Valley (1 farm) and Coqueddale (1 farm). One mixed sample with *L. caesar* (early July) occurred in a series of 10 from a farm in the Upper Tweed area, and one similar sample was received from the Cheviots (Catscleugh, late August). A mixed sample of *L. sericata* and *C. erythrocephala* occurred (early July), in a series of 9 from the lower Tweed basin; the remaining 78 samples from this region were pure *L. sericata*.

VIII. *The Solway Basin and Cumbrian Hills.*

This region comprises three main areas, the hills and dales of Galloway, the lowland plains of south Dumfries, Annandale and round the Solway, and the Cumbrian hills—the Lake District. The boundary continues from Brampton down the Pennine Scar

to Appleby, then south-west through the passes east of the Shap Fells, to Kendal and Morecambe Bay.

The Galloway hills are distinct from the rest of the Southern Uplands, approaching more to the western Grampian type in their deep transecting glens. The rainfall is high but the quality of the herbage good. The south coastal belt has a particularly mild climate, which is continued round the fertile plains bordering the Solway to the north, east and south. In the Cumbrian hills the steep-sided glens, rock outcrops and scree are reminiscent of the north-west of Scotland, but the quality of the herbage is good, and there is little of the waterlogged blanket moss encountered in the north-west, in spite of a comparable rainfall. The winters, relatively speaking, are mild.

The results of the survey are given in Table VI.

TABLE VI.

Area	Farms	No. of Samples	June		July		August		September	
Carrick ..	4	13	2 Ls	3 Ls 1 Ls+Lc+Ptn		3 Ls 1 Ls+Ptn 1 Ls+Lc+Ptn	1 Ls		1 Ls	
Galloway Plains	4	38	3 Ls	2 Ls 1 Ls+Lc	4 Ls	5 Ls 1 Ce	1 Ls	8 Ls 1 Ls+Lc	10 Ls	2 Ls
Solway Plains	1	2		2 Ls						
Penrith Basin	9	22		6 Ls 2 Ls+Lc 1 Ls+Ptn	5 Ls	1 Ls	1 Ls	3 Ls 1 Ls+Cv	1 Ls+Ce	1 Ls
Western Dales	7	37	4 Ls 3 Ls+Lc 1 Lc+Cv	3 Ls 4 Ls+Lc 1 Ls+Lc+Ptn	1 Ls 1 Ls+Lc+Ptn	4 Ls 1 Ls+Lc	1 Ls 1 Ls+Ptn	5 Ls 1 Ls+Lc 1 Ls+Ce	4 Ls	1 Ls
Southern Dales	3	6	1 Ls 1 Ls+Lc			3 Ls	1 Ls			

In the Galloway area, samples have been received from Carrick—the upland area of south-west Ayrshire—the Machers, or lowland plains of Wigtown, and the southern plains of Kirkcudbright. No samples were received from the Rhinns of Galloway, from the Glenkens area—the upland dales of Kirkcudbright or from the Nith valley.

The *Phormia* samples from the Carrick area were received from two of the four farms, in the case of one farm on two successive years. The absence of *Phormia*, and the relative scarcity of alternatives generally, from the lowland plains, is interesting.

The wide expanse of the Carlisle-Annandale lowland basin is represented by only two samples from a farm near Bewcastle.

The Cumbrian Mountain region, with its valleys radiating from the central dome of mountains, has been divided into three areas (1) the fertile Penrith basin, including the broad Eden Valley and those valleys which open into it, terminated southwards by the Shap summits, (2) the climatically favoured southern dales, with their low fells, and the Kendal, Windermere and Coniston valleys, and (3) the more exposed western dales and wild associated fells, from the Duddon to St. Bees Head.

The Penrith basin, sheltered from the prevailing westerly winds by the dome of mountains, and with a moderate rainfall, is remarkably free of alternatives; the sample containing *Phormia* came from the shoulder of the Dome, on the northern slopes of High Pike, as also did one of the two *L. caesar* samples, the other being from Ullswater. In violent contrast to this is the Western Dales area, wet, cloudy, and exposed, with nearly half the total samples containing one or more alternative species. *Phormia* was recovered from Calderbridge, Ravenglass, and the Ulpha moor, while *L. caesar* occurred in one or more samples from all seven farms.

South of Eskdale, where the Black Combe reaches to the coast, two farms belonging to the same man, one a rough fell grazing on the Combe, the other, adjacent, but on the fertile coastal plain, were chosen for comparison. Of eight samples from the lowland farm, seven were *L. sericata*, the eighth a mixed *L. sericata* and *L. caesar*. Only two samples were received from the adjacent fell, but both of these were mixed *L. sericata* and *L. caesar*.

Of the six samples received from the southern fells and dales, four were from a lowland-type farm, at Hutton; they were all *L. sericata*. Of the remaining two, one, from Grasmere, was *L. sericata*, the other, from Lambrigg Fell, contained *L. sericata* and *L. caesar*. No conclusion can be drawn as to how the southern fells compare with their wilder western brothers.

MacDougall's two Cumberland samples were both from Whitehaven; one contained mixed *L. sericata* and *C. erythrocephala*, the other *L. sericata* only.

IX. The Pennines and Yorkshire.

This region is defined to the west by the escarpment edge of the Central and Lower Pennine Moors, the boundary then continuing south of the Peak and running somewhat arbitrarily to the east coast south of the Yorkshire Wolds. The region thus includes the bleak Northern Pennines, with their shelterless peat moors, the lower highlands of the Central and Southern Pennines, with their fertile valleys and sheltered dales, and the eastern plains and moors of Yorkshire and Durham.

It has been intended to omit this region from the survey, as Dr. R. Carrick, Leeds University, informed me in 1938 that he was carrying out a blowfly survey of Yorkshire. However, a number of samples were received in 1941 from the northernmost area of the region, as follows:—

Haltwhistle. 1 farm. 6 samples. All *L. sericata*.

Alston. 1 farm. 5 samples. 3 *L. sericata*, 1 *L. sericata*+*L. caesar* late July, 1 *L. sericata*+*P. terraenovae*, early July.

Blanchland. 2 farms. 3 samples. All *L. sericata*.

Upper Weardale. 1 farm. 2 samples. 1 *L. sericata*, 1 *L. sericata*+*L. caesar* late August.

Sunderland. 1 farm. 10 samples. 8 *L. sericata*, 1 *L. sericata*+*L. caesar*, late June, 1 *C. erythrocephala*+*C. vomitoria*, late August.

X. North Wales.

This has been taken as the high plateau containing the Snowdon and Berwyn ranges, with its coastal fringe of plain—the pre-Norman "Gwynedd" division of Wales. The boundary runs from the Dyfi along the south-east escarpment of the Welsh hills to the mouth of the Dee.

Both North and South Wales suffer from a high rainfall, and little sunshine; the winters, especially in the Uplands, are cold, though not excessively so, and the spring late in coming. The grazing is mostly good quality limestone and siliceous grassland, but with considerable areas of bog. Rock and scree are much in evidence, and the steep faces of the glens combine with these disadvantages to reduce the habitability of the country for sheep, yet the stocking is surprisingly high.

Table VII gives the distribution of species for the northern region.

The areas in the table are as follows:—

Anglesey is the low-lying ground to the west of the mountains; it includes the island of Anglesey, the coastal strip of Caernarvon, and the low peninsula of Llyn. Only *L. sericata* was received from this area. The central plateau is the high ground from the Snowdon to the Berwyn range, including the Denbigh moors and Bala

basin. The eastern slopes of the Berwyn range, overlooking the Oswestry-Welshpool plain, forms the south-east area. From these two only 18 samples were obtained, in two of which *L. caesar* occurred, but the numbers are too limited to allow an opinion of the relative frequency of this species on the high ground.

East of the Conway, the narrow coastal strip broadens out into the wide Vale of Clwyd, and, beyond the Clwydean ridge, the plain of the Dee. This low ground and the Clwydean or Flint hills is the north-east area. This area, except for the Clwydean ridge, has a lower rainfall than the rest of the region.

In three farms *L. caesar* occurred, in each case in one of a series of samples.

TABLE VII.

Area	Farms	Cases	May	June		July		August		September
Anglesey ...	4	13	1 Ls	1 Ls	1 Ls	3 Ls		4 Ls	2 Ls	1 Ls
Central Plateau	5	9				1 Ls		5 Ls	1 Ls 1 Ls+Lc	1 Ls
North-east ...	4	26	1 Ls	4 Ls 2 Ls+Lc	5 Ls	1 Ls	6 Ls	3 Ls	2 Ls 1 Ls+Lc	1 Ls
Tremadoc basin	7	28	1 Ls		1 Ls 2 Ls+Lc	3 Ls 1 Ls & Lc 1 Lc	4 Ls	7 Ls	8 Ls	
West Merioneth	13	60		4 Ls 1 Ls+Lc	5 Ls 1 Ls+Lc 3 Lc 2 Cc	6 Ls 1 Ls+Lc 1 Lc	10 Ls 1 Ls+Lc 1 Lc	6 Ls 1 Ls+Lc	9 Ls	4 Ls 4 Ls
South-east ...	3	9	2 Ls	2 Ls		2 Ls 1 Ls & Lc		2 Ls		

Between the Caernarvon and Merioneth Highlands a basin of lowland plain and radiating valleys lies at the head of Tremadoc Bay the Tremadoc basin. The farms in this area are on the foothills or slopes of the surrounding mountains and on three of the seven farms *L. caesar* was recovered.

The West Merioneth area is a much similar area, consisting of the basin of the Mawddach and Eden, and that of the Dyfi, linked by a coastal strip of plain of varying breadth, and separated by the Cader Idris and Mawddwy ridge. *L. caesar* occurred in 10 samples, either pure or mixed with *L. sericata*, and two samples of *Calliphora* were also obtained. The incidence of alternatives is the more striking when the farms are divided into hill farms and farms on the coastal fringe. Thirty-one samples were received from coastal farms, and, except for one containing *Calliphora*, they were all *L. sericata*. Of 29 samples from inland, 11 contained alternative species.

XI. South Wales.

This region has for eastern border the eastern escarpment; the line runs from Welshpool down the east of the Clun forest and Radnor Forest uplands, east of Black Mountain, and down the Usk valley to the Bristol Channel.

The south region of Wales does not present a startling contrast to the north region, in its physical or agricultural aspects, yet the blowfly results show a definite and outstanding difference. In only one sample, out of a total of 59 from 19 farms, did other than *L. sericata* occur; the one exception, a pure culture of *L. caesar* (early July), was one of eight samples from the southern slopes of the Dyfi basin (Pennant, Machynlleth).

The South Wales samples were distributed as follows :—

South-east slopes of the Berwyn range, north of Plinlimmon. 4 farms. 13 samples.

Aberystwyth coastal basin. 4 farms. 18 samples.

Port Cardigan basin. 2 farms. 3 samples.

Eastern Uplands—Usk and Wye basins. 5 farms. 11 samples.

Southern coastal plains. 4 farms. 14 samples.

XII. *Central England.*

This region has been taken as the Midland plateau region, extending east to the Lincoln Edge and the Chilterns and north-west through the Midland gap to the Lancastrian plain. Southwards, it is bounded by a line drawn from the northern escarpment of the North Downs, through the Vale of Kennet to the Avon. The region thus includes three main river basins, those of the Thames, Severn and Trent, and two areas of lowland plains in the north-east and north-west respectively, but it is for the greater part upland plateau, occasionally rising to higher ridges, as in the Shropshire, Cotswold and Chiltern hills.

The central and north-west areas of this region are principally industrialised, but the south, south-east and, to some extent, the north-east, are agricultural, a mixed farming being the rule, with emphasis on cattle and sheep in the Uplands, and on crops in the river basins.

All samples from this region were *L. sericata*. They are distributed as follows :—

N.W. (Lancastria). 2 farms. 3 samples.

West (Shropshire). 2 farms. 8 samples.

N.E. (Lincoln and Northants). 2 farms. 22 samples.

S.E. 5 farms. 10 samples.

S.W. 4 farms. 6 samples.

XIII. *The Eastern Plains.*

This region consists of the low plain extending eastwards to the North Sea from the escarpment of the Chalk Uplands. It corresponds to the ancient kingdom of Anglia, except that the fens, then a bordering swampland, and the agricultural community of Lincolnshire, have been included.

The region is entirely agricultural, with highly developed and often unique systems of mixed farming. Climatically, it is dry and sunny, with continental extremes of warm summers and cool winters.

Twelve samples were received from a group of five farms in Lincolnshire, and 21 samples from five farms in Suffolk. All were *L. sericata*, except for one sample from Trimley (late September), one of a series of eight, in which *C. erythrocephala* occurred.

XIV. *Southern England.*

This region is the Downland, extending west to the plain of Somerset, and including the Salisbury Plain and Mendip Hills.

The climate is fairly dry, warm, with a very high proportion of sunshine in the coastal areas, and, except for the higher exposed uplands, exceptionally mild in winter. Sheep farming predominates in the east, and on the downland, with cattle farming becoming increasingly important westwards, and being predominant in the Somerset plain.

Three mixed samples containing *L. caesar* occurred in a series of 13 from a flock at Wye. Two were in late July, the third in early August. All other samples were

L. sericata; they included 32 samples from four farms in Kent, Surrey and Sussex, four from a farm in Hants, and three from two farms in Somerset.

XV. South-west England.

This is the region of high ground and moor west of a line from Watchet on the Somerset coast, through the Quantock Hills, to Chard, and then to Lyme Regis on the Channel coast.

The moorlands in the west have much rock or peat, but the better quality grazing of Exmoor supports a considerable sheep population. The fertile valleys and plains of the south are intensely cultivated, but cattle farming is the predominant agricultural activity of the peninsula. The climate is warm and humid, with exceptionally mild winters. Although the rainfall is high there is a high proportion of sunshine.

The absence of alternatives from this hilly region of high rainfall was unexpected. Only one sample, from the lowland basin of the Exe mouth, in early June, contained *L. caesar*. Six samples were received from two farms on the Exmoor coast, and two from Exmoor; the remaining 57 samples were received from four farms in the broad Exe basin, two of them in the coastal plain and two inland between the Exmoor and Dartmoor uplands. Further samples from hill farms on the moors, on the north and west coast, and from Cornwall are desirable before this region can be compared with the hill country of Wales, Cumbria, or Western Scotland.

XVI. Ireland.

Of the total of 97 samples identified, only two contained *L. caesar*. Both were from the Lough Foyle basin, and both occurred in early August. The distribution of samples is as follows:—

Co. Derry, Antrim and Co. Down. 4 farms. 40 samples.

Donegal and Tyrone. 3 farms. 5 samples.

Connaught. 5 farms. 16 samples.

Queen's County and Kildare. 4 farms. 19 samples.

Wexford and Waterford. 6 farms. 14 samples.

No samples were received from Munster. The Connaught samples, except two from near Newport, Mayo, were all from the lowland plains round the head of Galway Bay. Only one sample was received from Donegal. The results cannot, therefore, be taken as representative for Ireland, and the possibility of a high proportion of alternatives occurring in the western hill country of Donegal, Connaught and Munster remains unexplored.

XVII. The Cooper Field Research Station.

The results of the survey of strikes in the experimental flocks at the Little Gaddesden Field Station should be considered in conjunction with those for the Central England region. In 16 out of 276 cases *L. caesar* occurred along with *L. sericata*, and *C. erythrocephala* occurred in three cases. It must not be overlooked, however, that the samples from the experimental flocks represented all the cases of strike occurring, whereas the samples sent in from outside farms are a small proportion only. The distribution of the alternatives in half-month periods is as follows:—

	May	June	July	Aug.	Sept.	Oct.
Cases including <i>L. caesar</i> ...	—, 1	4, 1	2, 2	4, —	—, 1	—, 1
Cases including <i>C. erythrocephala</i> ...	—, 1	—, —	—, —	1, —	1, —	—,

FURTHER NOTES ON CERTAIN SPECIES.

The Caesar Group.

On first examination, flies were assigned to this category if they had black basicostal scales, and two pairs of postsutural acrostichal bristles. They were set aside for specific determination later, as the species in this group—*L. caesar*, *L. illustris*, and *L. ampullacea*—cannot readily be separated even in the male, and cannot with certainty be separated in the female. The principal diagnostic character in the male is the shape of the genitalia, although *L. illustris* can be provisionally separated on the less close apposition of the eyes, and *L. ampullacea* on the hairy hypopygial region. Unfortunately, when the stored material was overhauled for final determinations, it was found that a high proportion had been ravaged by the beetle, *Ptinus tectus*. Of the undestroyed samples, several contained females only, and no attempt was made to separate these. Thus, specific identification was made in only 65 of the original 131 samples of *L. caesar* type flies, and in these cases the identification refers only to the males.

No *L. ampullacea* was identified. Six of the samples were found to contain *L. illustris*, alone in two and mixed with *L. caesar* in four cases. All the remainder, judging from the males, were pure *L. caesar*.

The distribution of the *L. illustris* cases is interesting. Two occurred in Argyll, one in Fife, two in S.E. England, and the sixth in Devon. If one separates the determined *caesar*-type samples into those obtained from the hill areas of Scotland, northern England and Wales on the one hand, and the lowland belt of Central Scotland, south and east England and the lowland basin of the Exe in Devon on the other, the following interesting result is obtained :

					<i>L. caesar</i>	<i>L. illustris</i>
					cases	cases
Highland areas	...	...	...	...	53	2
Lowland areas	...	...	...	...	12	4

Haddow and Thomson's results may similarly be divided :

					<i>L. caesar</i>	<i>L. illustris</i>
					cases	cases
Ayr and Arran	...	...	...	...	4	2
Argyllshire	...	...	...	...	6	0

It would thus appear that *L. illustris* is much more common in lowland strikes than in those of hill country.

Muscina spp.

Larvae of *Muscina* spp. occurred in three samples :

Newport, Mayo 8.6.39, hindquarters of a hogg.

Forgandenny, Perth 24.8.39, hindquarters of a shorn ewe.

Hesket Newmarket, Cumberland ... 25.6.41, on a sore on a newly shorn hogg.

In this last case 1 specimen occurred along with *L. sericata* and *L. caesar*; in the other two instances two or three larvae were present, along with *L. sericata*.

The very rare occurrence of such larvae makes it improbable that they are of any importance in cutaneous myiasis. The cases have not been included in reckoning the incidence of alternative species.

Haddow and Thomson record three instances in which they bred out a single *Muscina*, along with *L. sericata* and *P. terraenovae*, from cases of strike.

DIFFERENTIAL SEASONAL DISTRIBUTION.

I suggested in an earlier paper (1937), that *Phormia terraenovae* seems to be restricted to early summer as a striking species. Morison's (1942) note on the occurrence of the species in N.E. Scotland confirms this conclusion. *Caesar*-type flies, on the other hand, would appear from casual examination to be equally ready

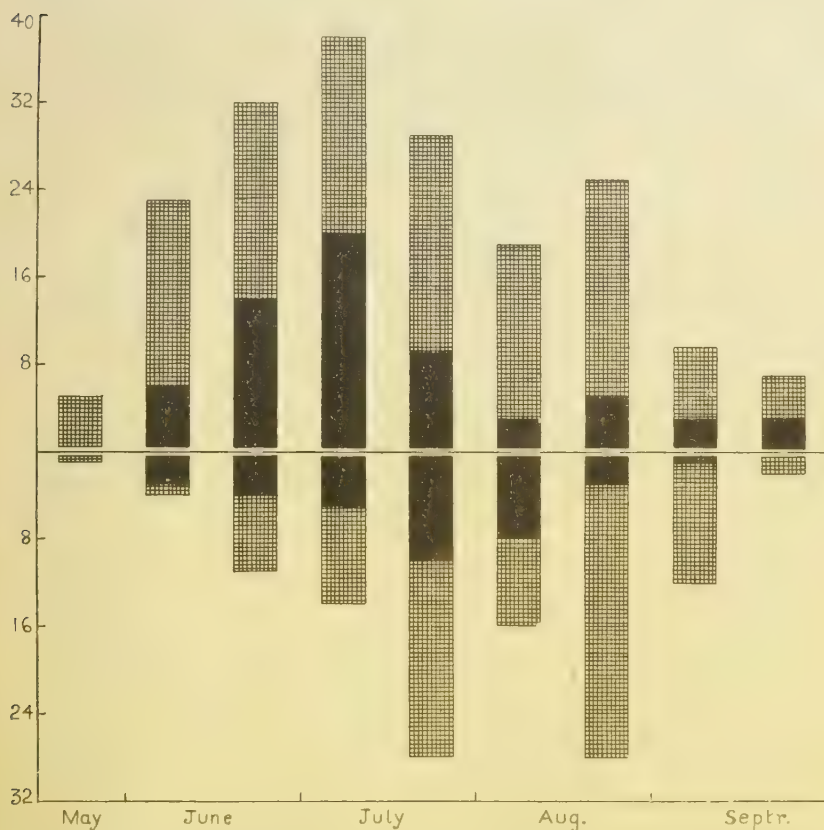


Fig. 2. The incidence of *L. caesar* (solid part of column) in strikes on *caesar*-infected farms, in half-monthly intervals, in relation to the number of strikes examined (total column). Upper half of diagram—strikes in adults; lower half—strikes in lambs.

Note the relative decrease of this species in the late season strikes.

to attack sheep in autumn and summer. The periodicity of the different species can obviously not be assessed from their relative frequency in the total of samples received, because a farm where a given alternative species occurs might only send samples for part of a season, or "pure *L. sericata* farms" might swamp a peak season for, say, *Phormia*, by sending a large number of samples at that time. Some idea of the relative frequency of "alternatives" at different seasons may, however, be obtained by considering only those farms where such alternatives are known to occur. The column diagrams in figs. 2 and 3 represent the distribution of investigated cases of strike on farms from which *L. caesar*-type and *Phormia terraenovae* respectively had been obtained. The solid part of the diagram represents the number of cases in which the given "alternative" was present. It is apparent that with both alternatives there is a higher relative incidence in the early part of the season, up to July, than in the later part.

Since the host type changes throughout the season from unshorn adult to lamb, and later to shorn adult and lamb, an apparent break in the incidence curve for a given species might conceivably be due, not to the unsuitability of that particular time of the year, but to the absence of a suitable host type. In the diagrams, the incidence in adults and in lambs has been separated, and it is clear that with both species the decrease in relative incidence in July is not due to a change of host from ewe to lamb, since it is obvious, in the case of *Phormia*, when the lamb strikes are omitted, and appears in both the adult and lamb incidence in the case of *Lucilia*.

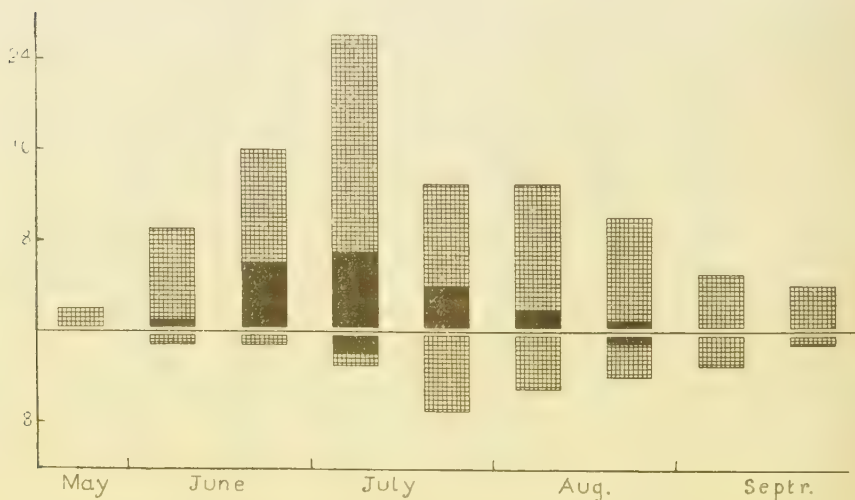


Fig. 3. The incidence of *P. terraenovae* (solid column) on *Phormia*-infected farms, in relation to the number of strikes examined. Upper half of diagram—strikes in adults; lower half—strikes in lambs. Note the decrease in relative incidence of this species after July.

The number of cases of infestation of *Calliphora* spp. is too small to yield information by the above treatment. In fig. 4, the incidence is plotted of investigated strikes on farms from which either of the species was recorded. Adult and lamb strikes have not been separated. There is no evidence of a seasonal differentiation in the incidence of *C. erythrocephala* infestations, but there is a suggestion that *C. vomitoria* may be confined as a striking species to the cooler extremes of the fly season.

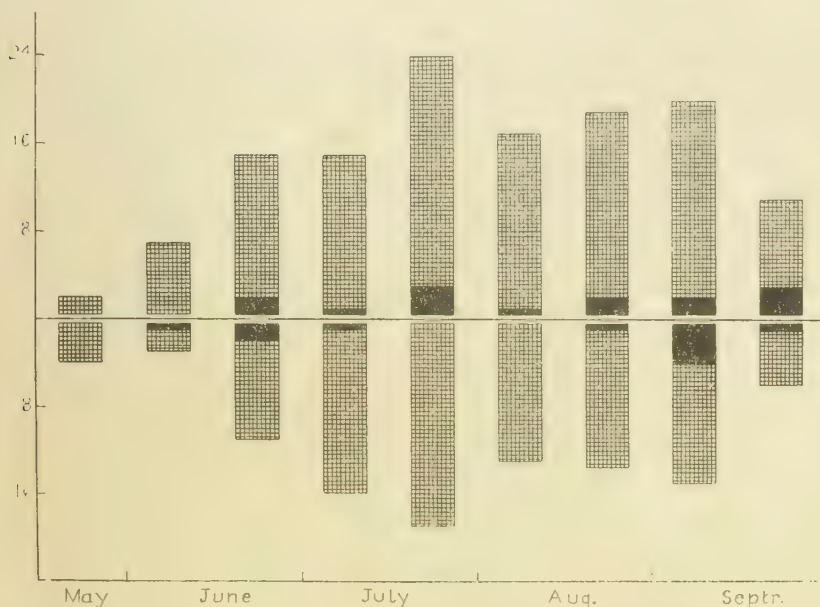


Fig. 4. The incidence of *C. erythrocephala* (upper half of diagram) and *C. vomitoria* (lower half) on *Calliphora*-infected farms, in relation to the number of strikes examined. Adult and lamb strikes combined. Note the absence of *C. vomitoria* from mid-season strikes.

INTERPRETATION OF THE SIGNIFICANCE OF SAMPLES.

The number of flies bred out from each sample varied from 1 to several hundred, slightly over 4 per cent. of the cases exceeding 100 flies. If these very large samples are ignored, and only the samples containing up to 100 flies considered, the mean number of flies bred out per sample is 29 (median 23). The distribution can most simply be shown as follows:—

No. of flies per sam- ple ...	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Proportion of sam- ples ...	22.8%	23.3%	16.1%	12.1%	7.5%	5.8%	3.7%	3.6%	2.8%	2.3%

The low, flat nature of the curve is clear; although nearly half the samples contained 20 or less, these are equally distributed between the two intervals, and there is no sharp drop towards the upper limit of the distribution.

This absence of any marked central tendency compels consideration of the effect of sample size on the probability of occurrence of "alternative" species. If the samples are divided into two classes, 20 and under, and over 20, and the proportion of occurrence of each alternative species calculated for each class, the following result is obtained:—

	<i>L. caesar</i> -type	<i>Phormia</i>	<i>Calliphora</i>
Samples containing 1-20 (446) ...	10.75%	1.12%	2.24%
Samples containing over 20 (518) .	10.8%	3.67%	2.12%

The same result is obtained if only those farms are considered on which alternative species occurred :—

	<i>L. caesar</i> -type	<i>Phormia</i>	<i>Calliphora</i>
1-20 (110 cases)	35.5%	2.7%	4.5%
Over 20 (127 cases)	34.6%	11.8%	4.7%

The *Phormia* proportions indicate a significant association with sample size (homogeneity test—all samples, $0.05 > P > 0.02$; "alternative" farms only, $P = 0.02$).

The high proportion of *L. caesar* infestations makes it possible to use rather narrower class intervals, and the same result is obtained. Thus, taking groups of 20-40 cases ("alternative" farms only) :—

Sample size	1-5	6-10	11-15	16-20	21-25	26-40	41-70	Over 70
Cases	37	25	26	22	23	36	40	28
Proportion of <i>L. caesar</i> (percentage)	30	48	38	27	39	30	33	39

Thus it would appear that the size of the sample does not materially affect the probability of individuals of *L. caesar* or *Calliphora* spp. appearing, but is important as regards *Phormia*.

TABLE VIII.

Individuals per sample	Total flies	<i>L. caesar</i>	<i>Phormia</i>	<i>Calliphora</i>
1-10	1,102	90 (8.2%)	10	16
11-20	2,960	144 (4.9%)	9	32
21-30	3,328	142 (4.3%)	28	23
31-40	3,245	123 (3.8%)	30	37
41-50	2,785	191 (6.9%)	12	5
51-60	2,530	48 (1.9%)	12	105
61-70	2,150	121 (5.6)	68	6
71-80	2,360	110 (4.7%)	5	1
81-90	2,020	179 (8.9%)	12	84
91-100	2,160	2 —	19	3
Over 100	6,193	232 (3.8%)	177 (2.86%)	1 —
Total ...		(4.48%)	(1.23%)	(0.98%)

The material can also be examined by considering, not the relative proportions of cases, but the proportions of actual flies involved (Table VIII).

Again, *L. caesar* shows no evidence of relationship to sample size. The numbers of *Phormia* and *Calliphora* are too low to be examined in sample intervals of 10, when grouped so as to give reasonably large numbers; the *Phormia* figures show a consistent increase with increasing sample size, whereas the *Calliphora* figures show no significant relationship.

Since *L. caesar* frequently occurs in low numbers in mixed infestations, the apparent anomaly of sample size not affecting the probability of its appearance was further investigated. The species occurs in any proportion, 1 per cent. to 100 per cent., in infestations; the distribution of different proportions is shown below. Only samples of 10 individuals or over are included, since smaller samples could obviously not be represented in the first class-interval:—

Percentage of <i>L. caesar</i>	1-10	20	30	40	50	60	70	80	90	99	Pure <i>L.c.</i>
All farms ...	26	14	4	7	3	2	6	2	0	6	13
Hill farms ...	11	12	4	6	3	2	6	2	0	5	13

"Hill farms" refer here to "alternative" farms in areas where *L. caesar* is common, *i.e.* lowland areas in which a few isolated cases of *L. caesar* occurred among a large number of samples are excluded. Two points of interest are brought out. Firstly, *L. caesar* infestations would appear to consist of two main types: (a) pure infestations, and (b) mixed infestations in which *L. caesar* is present usually in low proportion (under 20 per cent.). Secondly, when rare cases of *L. caesar* infestation are included (lowland farms) the incidence of "low proportion" cases is increased.

Mixed Infestations: If the pure infestations of *L. caesar* are omitted from consideration, the distribution of the cases of mixed *L. caesar* infestation among the size groups of samples shows again divergence according to whether all farms, or "alternative" farms only, are taken. The size groups have been adjusted so as to give reasonably uniform numbers in each group:—

All farms				
Size of sample ...	2-10	11-20	21-50	Over 50
No. of samples	186	217	289	208
No. of <i>L. caesar</i> cases	10	20	32	19
Proportion ...	5.4	9.2	10.7	9.1

Test for independence in the variations gives $\chi^2=4.088$, *i.e.* the probability of these being chance variations lies between 0.2 and 0.3:—

Alternative farms				
No. of samples	38	42	68	51
No. of <i>L. caesar</i> cases	10	16	23	15
Proportion	26	38	34	29

The probability of the deviations here being due to chance is in the neighbourhood of 0·7. That is, the distribution of mixed *L. caesar* cases appears to be less probably dependent on the size sample, in *L. caesar* areas, than when areas of sporadic occurrence of the species are included. In the latter case, there is a suggestion of a decrease of incidence of the species in samples of 10 or under, this conforming with the observed tendency for the proportion of *L. caesar* flies in a sample to be 10 per cent. or less. In *L. caesar* areas, on the other hand, the proportion is more likely to be over 20 per cent. of the total strike than under. Also, of those cases containing less than 20 per cent. of *L. caesar*, at least half are in the 11–20 per cent. group. The effect of sample size on incidence of mixed infestations is, therefore, inapparent in such areas.

That lowland farms, on which *L. caesar* is rare, tend to have a low proportion of individuals of this species in their mixed infestations is confirmed by the results for the Research Station (a relatively *caesar*-free farm); of the 9 cases of mixed infestation obtained in 1938–40, 6 had 10 per cent. or less *L. caesar*-type flies, and three over 10 per cent.

Pure infestations of *L. caesar*: If the distribution of the pure *caesar* infestations is examined in the same way as for mixed infestations, it is seen that the greatest incidence is in the lowest size group:—

Size of sample	1–10	11–20	21–50	Over 50
No. of samples (all farms) ...	222	224	303	215
No. of <i>L. caesar</i> cases ...	13	5	3	3
No. of samples ("alternative" farms)	61	48	71	54
No. of <i>L. caesar</i> cases ...	11	5	3	3

The data for "alternative" farms may be expressed as that proportion of *L. caesar* occurrence in each sample class which is pure:—

Sample size	2–10	11–20	21–50	Over 50
No. of <i>L. caesar</i> infestations	20	16	26	18
No. of pure <i>caesar</i> infestations	10	5	3	3
Proportion pure	50%	31%	12%	17%

The greater incidence in small size samples is obvious whichever set of data is used; it is also clear that pure infestations are almost entirely confined to *L. caesar*-type areas.

The above examination suggests the following conclusions:—

- (1) *Phormia terraenovae* is more likely to be recovered from large samples than from small ones.
- (2) This does not appear to apply for *L. caesar* and *Calliphora* spp.; the evidence for the latter is, however, too limited to allow of detailed examination.
- (3) Infestations of *L. caesar* can be divided into two groups. A small minority occurs sporadically in areas where alternative species rarely strike sheep. These are almost always mixed infestations of *L. caesar* and *L. sericata*, and *L. caesar* is generally present in low proportion, i.e. the size of the sample will affect the probability of detecting such cases.

- (4) The majority of cases of *L. caesar* infestation occurs in certain hill areas, and may be either pure or mixed with *L. sericata*. In the mixed samples the sample size is relatively unimportant, *i.e.* the species is usually present as a relatively high proportion of the strike.
- (5) Samples containing only *L. caesar* are usually of small size.

The last two conclusions might be held to suggest that in "*caesar*" areas the species is often a primary; that cases of pure infestation are usually early cases, before the ubiquitous *L. sericata* has begun to appear as secondary to the original infestation of *L. caesar*, and consequently not many large larvae are readily available for collection by the shepherd.

In lowland areas, *L. caesar* would appear to act principally as a secondary species, arriving late on the scene and so appearing in low proportion in the samples.

DISCUSSION.

The investigation of the species concerned in sheep myiasis in the different regions of Britain shows that *L. sericata* is, everywhere, the principal sheep maggot fly of this country. Even in the western Scottish Highlands, where the highest proportions of other species occur, it is still the dominant species. In addition to *L. sericata*, at least six other species occur, *L. caesar* and *illustris*, *C. erythrocephala* and *vomitaria*, *P. terraenovae* and *Muscina* sp.; two of these, *L. caesar* and *P. terraenovae*, occur in sufficiently high frequency in certain regions to be regarded as economically important.

An interesting feature of the results is the tendency for these "alternative" species to have common areas of maximum incidence; the two species, *Phormia terraenovae* and *L. caesar*, are practically confined to the hill areas of north and north-west Britain, and the species of *Calliphora*, although less common in these areas, and relatively more common in lowland, eastern and southern areas, betray the same tendency.

The limitation to the north and north-west is apparently more rigid with *Phormia* than with *L. caesar*; it apparently does not occur in Wales, whereas *L. caesar* is fairly common in the northern Welsh hills, and it has not been recovered from the eastern Border Uplands. Also, its limitation to hill-land is more pronounced; it has not been recovered from the lowland belt of Scotland, which is flanked to the north and south-west by *Phormia* areas of hill-land (Haddow and Thomson, however, recovered it from low hill country in Ayrshire), and it appears to be completely absent as a striking species from lowland areas generally, whereas *L. caesar* occurs in low incidence throughout the southern areas, and is frequent in the central Scottish belt.

If the species other than *L. sericata* be grouped together, an interesting gradation in the incidence of these "alternatives," from north-west to south-east, becomes apparent. The combined records for the regions discussed in the text may be presented as follows:—

Scotland, north of Glenmore, and the Western Isles	137 cases	47% incidence of alternatives
Grampians and North-east	133 "	24% " "
Solway region	117 "	22% " "
Wales	204 "	11% " "
Border Uplands and Pennines	107 "	8% " "
South and South-west England	104 "	4% " "
Central and East England	82 "	1% " "

The results in the above grouping fall into four principal levels—47 per cent., 22–24 per cent., 8–11 per cent. and under 5 per cent. It is of interest that these four categories correspond to four major regions which may be delimited by lines running approximately north-south, thus :—

A line from Inverness to Glasgow separates off the north-west and the Western Isles, while the Grampians and north-east, the central Scottish plain and the Solway region might be limited by a line from the Pentlands to Morecambe Bay. East and south of this the Cheviots, Pennines and Wales form the third belt, beyond which lies the fourth region—the south and south-east.

It is interesting to compare the British incidence of alternative species, based on all available records, with that of Australia. The records for which detailed protocols were available are listed below. The more comparable results are those which exclude the experimental flocks in both cases.

	<i>L. sericata</i>	<i>L. caesar</i> and <i>L. illustris</i>	<i>Phormia</i>	<i>Calliphora</i>		Total cases
				<i>ery.</i>	<i>vom.</i>	
Own records	1,255	132	35	23	10	1,307
Haddow & Thomson ...	102*	27	7	5	2	107*
MacDougall	48			6		51
Maldwyn Davies ...	182			2		182
Percentage of Total ...	96.4	9.7	2.6	2.2	0.75	1,647
Less Exp. Farm results	95.7	10.4	3.1	2.4	0.9	1,371

* Approximate. (Thomson, private communication.)

Mackerras and Fuller (1937) give the following proportions for species in Australia, based on all available records (1,691 strikes), and on commercial flock records (1,088):—

	All records	Commercial Flocks
<i>L. cuprina</i>	81.5%	76%
<i>C. augur</i> and <i>C. nociva</i>	32.5%	35%
<i>C. stygia</i> and <i>C. australis</i> ...	20%	16%
<i>Ch. rufifacies</i>	7.6%	10%
<i>L. sericata</i>	4.2%	0.5%

The relative incidence of species in Britain is no doubt influenced to some extent by seasonal bias in sampling, since both *Phormia* and *Lucilia caesar* have an early season incidence. Mackerras and Fuller point out a similar bias in their records. It is clear, however, that in Britain the blowfly problem is much less complex, and those species other than the principal species much less important, than under Australian conditions.

SUMMARY.

i. A four-year survey, involving the investigation of over 1,000 cases of strike, has been made of the species concerned in sheep myiasis throughout the British Isles. In all regions, *L. sericata* is the principal maggot-fly. In Scotland, Northern England and North Wales, *L. caesar* is an important species. *Phormia terraenovae* has much the same distribution, as a striking species, as *L. caesar*, except that it apparently does not strike sheep in North Wales; in the areas where it occurs it follows *L. caesar* in importance. These two species are apparently capable of acting as primary flies. *Calliphora erythrocephala*, and, more rarely, *Calliphora vomitoria* occur fairly generally over the country, but only in very low incidence. Larvae of *Muscina* spp. have been recovered from only three cases, one each in Scotland, England and Ireland. The two closely related species, *L. caesar* and *L. illustris* have only been separated in a few instances, and there is not sufficient evidence for the latter species, but it would seem to be more common in lowland areas than in the north and west.

ii. The incidence of "alternative" species, *i.e.* species other than *L. sericata*, decreases from north-west to south-east of Britain; they occurred in 47 per cent. of strikes north and west of a line from Inverness to Glasgow, and in over 20 per cent. of the cases between this and a line from East Lothian to Morecambe Bay, south of the Lake District. In the fringe of hill country east and south of this, *e.g.*, the Cheviots, Pennines and Wales, about 10 per cent. of cases contained "alternative" species. Farther to the south-east and south "alternatives" were rare.

iii. Within the above belts of territory, the "alternative" species appear to have certain common regions which are favourable for the striking habit, although the limits of strike-distribution for each species are apparently not quite coincident. These "favourable regions" are discussed in the text. With *Phormia terraenovae* the habit appears to be restricted to favourable regions, where it occurs in moderately high incidence; with *L. caesar* strike occurs in relatively high incidence in favourable regions, but is also present, in low proportion, throughout the country, while the *Calliphora* species strike in low proportion in favourable regions, and sporadically elsewhere.

iv. *Phormia* and *L. caesar* have a higher relative incidence in the first half of the fly season than in the later half; *C. vomitoria* may be restricted to the extremes of the season—May, June and September.

ACKNOWLEDGEMENTS.

This survey was possible only because of the enthusiasm of sheepmen for all that pertains to sheep, so that in spite of frequent inconvenience, their cooperation was offered and maintained. To the many scores of farmers and shepherds who have collaborated I can only express collectively my gratitude.

Their cooperation was secured, in the first place, through the active interest and assistance of several of the Agricultural Colleges and Institutes, through the good offices of the Sales Department of Cooper, McDougall & Robertson, Ltd., and by the exploitation of all personal friendships which might conceivably be of assistance, as well as of a fairly wide circle of acquaintances among practical sheepmen. It is impossible to mention here all those who have helped to make contacts for me, but I would like, in thanking them all, to make special mention of my indebtedness to the late Dr. R. P. Hobson, who organised for me the survey of North Wales, to Dr. A. Milne, who arranged for the Lake District samples, and put me in touch with several farmers in other areas, and to Dr. A. E. Cameron, who enlisted on my behalf the aid of the County Organisers in the east of Scotland, and gave much personal attention to the organisation of the survey.

References.

- BOS, J. Ritzema. (1891). Tierische Schädlinge u. Nützlinge. Berlin.
- BROWN, G. T. (1902). J. R. agric. Soc. England **63**, p. 416.
- CARPENTER, G. H. (1902). Econ. Proc. R. Dublin Soc., **1**, p. 132.
- DAVIES, W. M. (1934). Ann. appl. Biol., **21**, p. 267.
- HADDOW, A. J. & THOMSON, R. C. M. (1937). Parasitology, **29**, p. 96.
- MACDOUGALL, R. S. (1904). Trans. Highl. agric. Soc. Scot., **16**, p. 128.
- . (1909). *Ibid.*, **21**, p. 135.
- MACKERRAS, I. M. & FULLER, M. E. (1937). J. Coun. sci. industr. Res. Aust., **10**, p. 261.
- MACLEOD, J. (1937). Proc. R. ent. Soc. Lond., (A) **12**, p. 127.
- MORISON, G. D. (1942). Nature, **149**, p. 358.
- NEUMANN, L. G. (1892). Parasites and parasitic diseases of domesticated animals. (Transl. G. Fleming.) London.
- RITCHIE, J. (1934). Scot. J. Agric., **17**, p. 249.
-

MEASUREMENTS OF TEMPERATURE AND LIGHT IN ARTIFICIAL
POOLS WITH REFERENCE TO THE LARVAL HABITAT OF *ANOPHELES*
(*MYZOMYIA*) *GAMBIAE*, GILES, AND *A. (M.) FUNESTUS*, GILES.

By A. J. HADDOW, B.Sc., M.B., D.T.M. & H.

Medical Research Council Junior Fellow in Tropical Medicine.

Important results obtained by Thomson (1940) have shown that the breeding of *Anopheles minimus* in Assam is controlled to a certain extent by a single physical factor, the temperature of the breeding water. He has demonstrated that certain natural waters regularly exceed the thermal death-point of the larva of this species, while other more resistant larvae are able to survive in such habitats. It was felt that a similar state of affairs might exist in Africa in the case of *A. gambiae*, which breeds in exposed pools and puddles, and of *A. funestus*, breeding waters of which are usually shaded by standing herbage. Two series of light and temperature readings were carried out at Kisumu, Kenya Colony, to investigate the daily cycle of temperature and light intensity as it affects the larvae of these two species. The findings for *A. funestus* also apply to species such as *A. costani* and *A. pharoensis*, which select similar breeding places.

It was at first intended to carry out the tests in natural pools. This plan was discarded on account of the difficulty of finding exactly comparable pools. The measurements were finally made in large pans (Karais) at Kisumu Native Hospital. These are regularly used by Mr. J. O. Harper for the purpose of maintaining a dry-season stock of *A. gambiae*. The pans, which are about 1 foot in diameter by 8 ins. deep, are sunk flush with the ground. They are half-filled with earth. The water is normally clear and fills the pans almost to the brim. The first readings were made with three pans. One contained clear water, one muddy water and one clear water with growing grass 1 ft. high. Hourly readings of temperature and light intensity were made during 24 hours, from midnight to midnight. Temperature readings were taken with the thermometer just submerged in the middle of the pans, the thermometer being shaded from the sun. Light readings were taken at the water surface in the middle of the pans. Air shade temperatures were taken from a thermometer suspended in a Stevenson screen. At no time were the pools shaded from the sun, except during the actual temperature readings. The second series of readings was an exact repetition of the first, but 3 extra pans were included. These were shaded by two thicknesses of papyrus matting giving unbroken shade at heights of 1, 2 and 3 feet respectively. They were included to allow comparison with the broken shade given by the standing grass. Three were used, as it was thought that the freer circulation of air under the higher mats might affect the water temperature. This was not the case, and the results in all three were practically identical. Only the pan with matting at a height of 1 foot will be considered here. The pan with muddy water was included as it was thought that the suspended mud might absorb more heat than clear water. The results, however, were almost the same as those obtained in the clear-water pan and need not be discussed further.

The main results were as follows :—

Temperature readings (°C.).

	1st experiment			2nd experiment		
	Min.	Max.	Range	Min.	Max.	Range
Stevenson screen	18.0	27.0	9.0	19.5	30.5	11.0
Grassy pool	20.0	27.0	7.0	19.5	26.0	6.5
Open pool	19.0	34.5	15.5	18.0	36.5	18.5
Pool with mat...	—	—	—	18.5	25.0	6.5

Maximum light intensities (Foot candles).

	1st experiment	2nd experiment
	3,500	1,800
Grassy pool	8,400	9,300
Open pool	—	520
Pool with mat		

With regard to the pool receiving unbroken shade from matting, it is seen that though the maximum light intensity was far below that of the grassy pool, its temperature cycle was essentially the same. It need not be discussed further.

To discuss the open and grassy pools in more detail : Hourly temperature readings and the hourly means are given in Table 1. In both series, the temperature range in the grassy pool was less than that in the Stevenson screen and less than half that in the open pool. The latter far exceeded the screen range on both occasions. By night, both pools approximated to the air temperature in the screen but by day, the temperature of the open pool rose far above that in the screen, while the temperature of the grassy pool remained below that in the screen. Further, in both experiments, the temperature of the grassy pool by night was higher than that of the open pool. The mean results are shown in fig. 1. It is thus obvious that standing

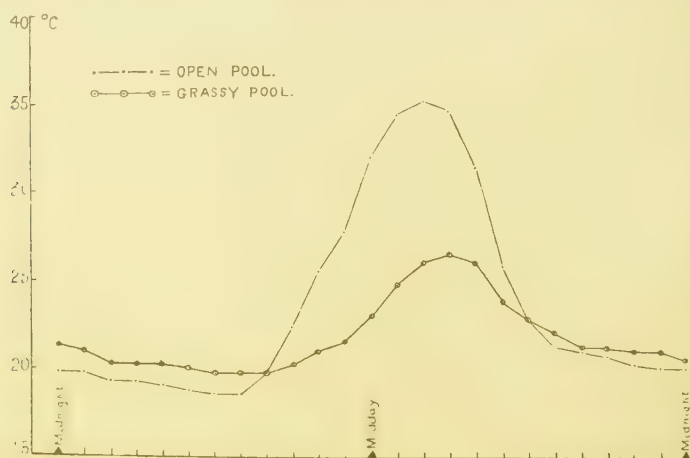


Fig. 1. Mean results of 2 sets of 24-hour temperature readings (°C.) in artificial pools.

TABLE I.
Hourly temperature readings (°C.).

Hour	Open Pool			Grassy Pool			Screen		
	Expt. 1	Expt. 2	Mean	Expt. 1	Expt. 2	Mean	Expt. 1	Expt. 2	Mean
12	19.5	20.0	19.75	21.5	21.0	21.25	19.0	21.5	20.25
1 a.m.	19.5	20.0	19.75	21.0	21.0	21.0	19.0	20.5	19.75
2	19.5	19.0	19.25	20.5	20.0	20.25	19.0	20.0	19.5
3	19.5	19.0	19.25	20.5	20.0	20.25	19.0	20.0	19.5
4	19.5	18.5	19.0	20.5	20.0	20.25	18.5	20.0	19.25
5	19.0	18.5	18.75	20.0	20.0	20.0	18.0	19.5	18.75
6	19.0	18.0	18.5	20.0	19.5	19.75	18.0	19.5	18.75
7	19.0	18.0	18.5	20.0	19.5	19.75	18.0	19.5	18.75
8	19.5	20.0	19.75	20.0	19.5	19.75	19.0	22.0	20.5
9	21.0	24.0	22.5	20.5	20.0	20.25	20.5	25.0	22.75
10	22.0	29.0	25.5	21.0	21.0	21.0	21.5	27.0	24.25
11	23.0	32.5	27.75	21.5	21.5	21.5	22.0	28.5	25.25
12	29.0	35.0	32.0	23.5	22.5	23.0	24.0	30.0	27.0
1 p.m.	32.5	36.5	34.5	25.0	24.5	24.75	26.0	30.5	28.75
2	34.5	36.0	35.25	27.0	25.0	26.0	26.5	30.0	28.75
3	34.0	35.5	34.75	27.0	26.0	26.5	27.0	29.5	28.75
4	31.0	32.0	31.5	26.5	25.5	26.0	26.0	28.0	27.0
5	24.5	27.0	25.75	23.5	24.0	23.75	22.0	26.5	24.25
6	22.0	23.5	22.75	22.5	23.0	22.75	20.0	25.0	22.5
7	21.0	21.5	21.25	21.5	22.5	22.0	21.0	23.5	22.25
8	20.5	21.5	21.0	21.0	22.0	21.5	20.0	23.0	21.5
9	20.5	21.0	20.75	21.0	22.0	21.5	20.0	19.0	19.5
10	20.5	20.0	20.25	21.0	21.0	21.0	20.0	19.0	19.5
11	20.0	20.0	20.0	21.0	21.0	21.0	19.5	19.0	19.25
12	20.0	20.0	20.0	20.5	20.5	20.5	19.5	19.0	19.25

grass has a remarkable insulating power—equal to that of two thicknesses of matting—and that larvae in open pools are exposed not merely to higher temperatures but also to much greater fluctuations of temperature. The light readings (Table II and fig. 2) are easily interpreted. Readings at dawn and sunset were very low (small fractions of 1 foot candle) and have been omitted. During the night readings were impossible.

TABLE II.
Hourly light readings. (Foot candles.)

Hour	Open pool			Grassy pool		
	Expt. 1	Expt. 2	Mean	Expt. 1	Expt. 2	Mean
6 a.m.	0.2	20	10.1	—	—	—
7	220	560	390	60	140	100
8	600	2,400	1,500	220	320	270
9	1,000	5,200	3,100	400	900	650
10	1,200	6,000	3,600	520	850	685
11	1,400	7,800	4,600	700	840	770
12	4,400	9,300	6,850	2,200	1,800	2,000
1 p.m.	8,400	8,400	8,400	3,500	940	2,220
2	7,800	6,800	7,300	3,000	540	1,770
3	7,000	4,800	5,900	2,400	600	1,500
4	1,000	1,700	1,350	600	520	560
5	140	400	270	100	140	120
6	60	130	95	40	70	55

At the moment, the implications of the temperature readings cannot be discussed fully with regard to the thermal death-points of the larvae concerned. De Meillon (1934) found that 15 *A. gambiae* larvae withstood a temperature of 45°C. for 1 hour and were all alive after 24 hours, while 15 *A. funestus* larvae all succumbed. The writer has carried out preliminary tests, using groups of 10 larvae and an exposure of 1 hour. The results obtained gave a thermal death-point of 42°C. for *A. gambiae* and 39°C. for *A. funestus*. These figures should not be regarded as final, but as the results of preliminary tests only. Further work on this line might give very instructive results. Measurements of midday temperature in actual breeding pools of *A. gambiae* at Kisumu were made during May and June 1940. The highest figure obtained was 36.5°C. Kisumu stands fairly high (over 3,700 feet), and it seems certain that much higher temperatures occur at lower levels.

Summary.

1. Two series of hourly measurements of temperature and light intensity, each extending over 24 hours, were made in artificial pools. One pool contained clear water, one muddy water, one standing grass 1 ft. high and one was completely shaded by papyrus matting at a height of 1 ft. Shade temperature records were kept in a Stevenson screen.

2. The results showed that the grass had a pronounced insulating effect on temperature. The range in the grassy pool was less than that in the screen and less than half than that in the open pool. The grassy pool was warmer by night and cooler by day than the open pool. No essential difference was noted between the temperature cycle of the clear open pool and the muddy open pool nor between the

grassy pool with broken shade and the pool receiving complete shade from matting. Maximum light intensity in the grassy pool was less than half that attained in the open pool.

3. It is concluded that not only do the breeding waters of *A. gambiae* reach much higher temperatures than those of such species as *A. funestus*, *A. costani* and *A. pharoensis*, but that they also undergo much greater temperature fluctuations.

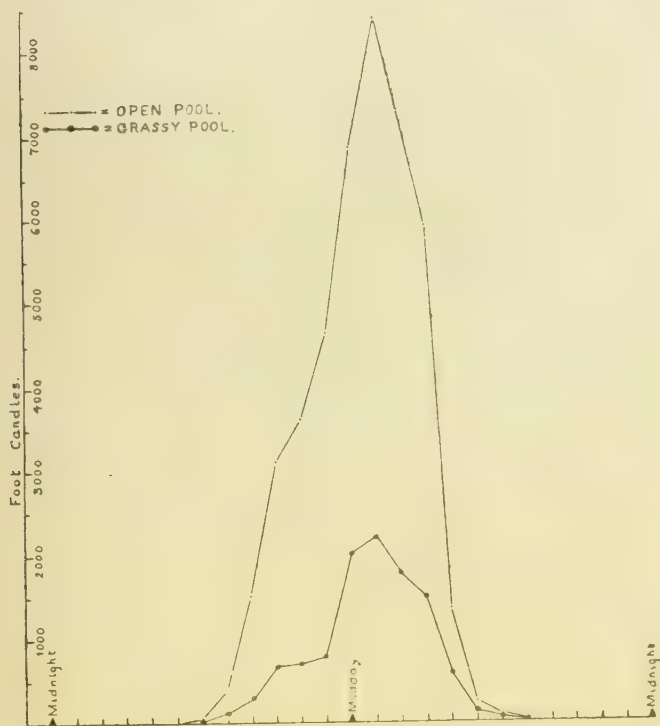


Fig. 2. Mean results of 2 sets of 24-hour light readings (Foot candles) in artificial pools.

References.

- DE MEILLON, B. (1934). Entomological studies. Observations on *Anopheles funestus* and *Anopheles gambiae* in the Transvaal.—Pub. S. Afr. Inst. med. Res., **6** no. 32, pp. 195-248.
- THOMSON, R. C. M. (1940). Studies on the behaviour of *Anopheles minimus*. Part III. The influence of water temperature on the choice and suitability of the breeding place.—J. Malar. Inst. India, **3**, pp. 323-348.

A SURVEY OF BRITISH SHEEP BLOWFLIES. II. RELATION OF STRIKE TO HOST AND EDAPHIC FACTORS.

By J. MACLEOD, D.Sc., Ph.D.
Cooper Technical Bureau, Berkhamsted.

In a previous paper (1943), I gave the breeding results from some 1,400 samples of larvae, obtained during 1934-41, from cases of sheep strike in the British Isles. The species involved and the geographical areas in which the different species affected sheep were discussed. In the present paper, I have collated the data collected during 1938-41, when rather full particulars were obtained about each sample, from the point of view of the relation of strike to season, host, and edaphic factors.

STRIKE IN GENERAL.

The Seasonal Strike Waves.

The earliest and latest cases from which samples were sent in were :—

4.5.38. Argyll. Shoulder of hogg ; 7.5.38. Oxford. Perinaeum of lamb.

7.10.39. S. Wales. Breech of lamb ; 24.10.38. Bucks. Breech of lamb.

The extreme cases observed in the Research Station flocks were :—

27.4.40. Breech of ewe ; 24.10.41. Shoulder of lamb.

Cases of strike in May and October are, however, relatively scarce, and June to September can be taken as the blowfly season proper.

During the fly season, the incidence curve tends to have a diphasic character, due to the interruption caused by shearing. This is clearly shown by the incidence figures for strike in the Research Station flocks. In addition to the 1938-40 records referred to in the earlier paper, records were kept of the strikes during 1941 and 1942, although no samples were taken. The figures are :—

Period	... to May	June		July		August		Sept.		Oct.	
		1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
Cases	... 22	67	12	28	44	46	58	27	11	12	5

It is interesting to examine from the records obtained the relative importance and the composition of the two waves of strike. The number of samples sent in cannot be taken as proportional to the incidence of strike on the farms concerned, for during a strike wave, the shepherds will sometimes be too busy to collect samples. Nevertheless, the number of samples sent in at different seasons should reflect, to some extent at least, the general shape of the incidence curve. Fig. 1 (curve A) shows the curve of the total samples sent in. This total obscures the diphasic nature of the incidence, because of a lack of synchronisation of the "trough" period throughout the country. This obscuring effect is brought out clearly by curves B, C and D. The figure shows how the overlapping of peak incidence may obscure the troughs present within homogeneous regions. An interesting point in

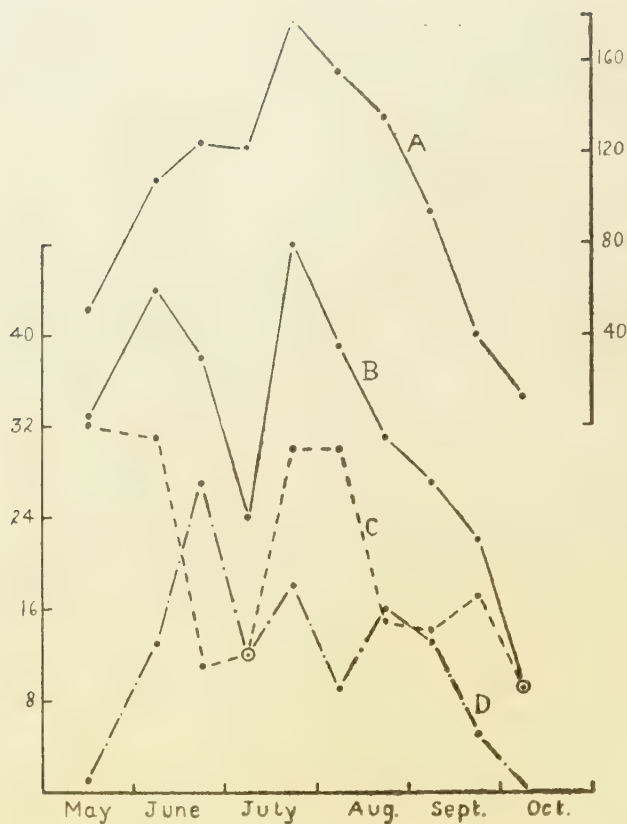


Fig. 1. Seasonal incidence of strike, as represented by samples sent in. A. All samples. B. England (excluding Wales). C. & D. The Northern Province (Northumberland, Durham, Cumberland and Westmorland), and the remainder of England respectively. Note the overlapping of the trough periods in C and D.

these curves is that both the C and D curves show a greater pre-shearing than post-shearing incidence (compare also the Research Station incidence), although the combined curve (B), fails to reveal this.

The change-over of host type during the blowfly season, from adult to lamb to lamb-plus-adult, is illustrated in fig. 2. Here the strikes have been grouped in the following categories:—

- | | | | |
|------|-----------------|-----|----------------|
| (A). | Mountain breeds | ... | Adults — total |
| | | | Adults — shorn |
| | | | Lambs |
| (B). | Lowland breeds | ... | Adults — total |
| | | | Adults — shorn |
| | | | Lambs |

In the curves for mountain breeds (A), the irregularity of the shearing dates is apparent from the fact that an appreciable number of strikes in shorn sheep occurred in June, although the woolled sheep strikes did not terminate until August. This scatter is due to the fact that several of the recorded strikes in mountain sheep were from sheep rearing a crossbred lamb on lowland farms, and consequently shorn abnormally early for their breed. This has obscured the trough which should become apparent in the adult incidence after shearing. The curves illustrate, however, the development of the lamb incidence, after shearing time.

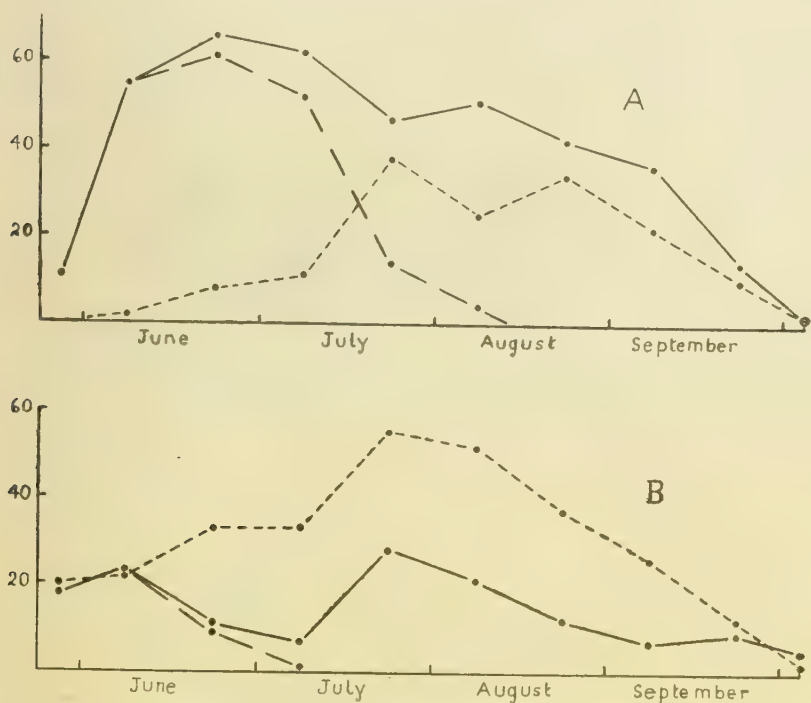


Fig. 2. Showing the switch over from adult to lamb as principal host, and the subsequent gradual recovery of the adult as host. A. Mountain breeds. B. Lowland breeds. The whole line and dotted line in each case represent adults and lambs respectively; the interrupted line indicates incidence in unshorn adults, subsequent to commencement of shearing.

The curves for lowland breeds (B), illustrate the recovery of the adult incidence curve after the June-July trough due to shearing, and the predominant rôle of lambs as hosts during the "trough" period. Because of the incomplete nature of the records the curves do not represent the seasonal picture in its entirety, but it would seem reasonable to infer four phases in the seasonal incidence:—

1. The pre-shearing phase dominated by ewe strikes.
2. The shearing trough, with only occasional lamb strikes.
3. A phase dominated by increasing lamb strikes, but showing recovery of the adult incidence with growth of wool.

4. The phase of both adult and lamb susceptibility.

A schematic representation of the relation of the four phases to the fly season in mountain and lowland breeds is given in fig. 3. The suitability of the fleece for strike, from the point of view of length (broken lines in diagram), is interrupted in the case of adults for a two to three month period after shearing; for the remainder of the year it is at its maximum suitability. Lambs increase in suitability, from two months or so after birth, until by the fourth to sixth month their fleece is completely suitable for strike, provided, of course, that the strike conditions—moisture and a source of attraction to the fly—are present. The season of fly activity (indicated in the diagram by dotted lines, arching to a peak in July/August), is more or less common to both mountain and lowland breeds, but the suitability of the hosts differs because of the different lambing and shearing dates. The later shearing of

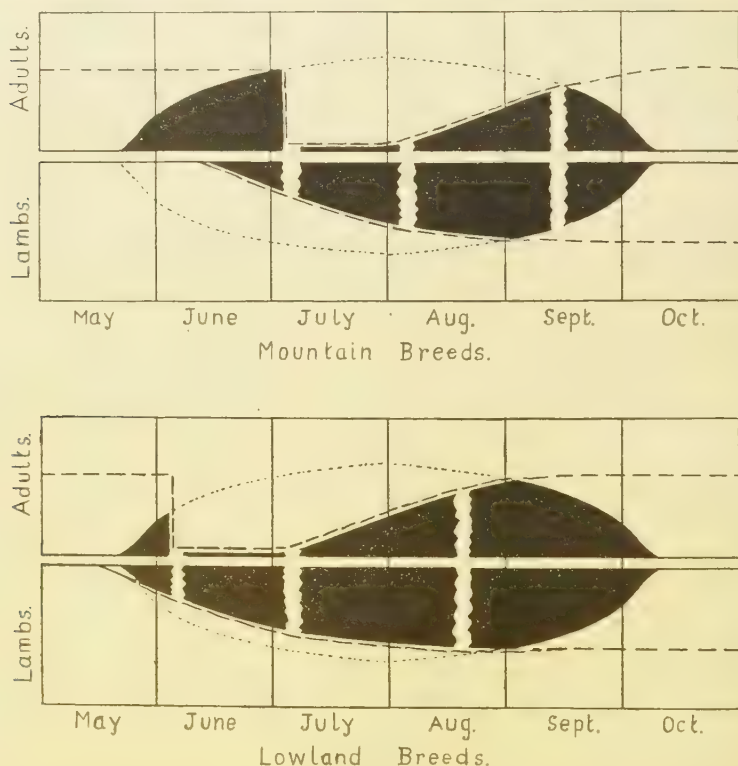


Fig. 3. The four phases in seasonal incidence, showing the relationship of fly activity, and lambing and shearing dates. The interrupted lines represent fleece suitability for strike, the dotted lines climatic suitability, *i.e.* fly activity. The broken zones indicate the limits of each phase.

mountain sheep results in an important part of the first phase being included in the fly season, so that this phase is relatively important. The fourth phase—of equal adult and lamb suitability—is abbreviated by the waning season. In lowland breeds, the earlier shearing largely escapes the first phase, but the earlier lambing results in the lambs attaining to full suitability during the peak of the fly season, so that the fourth phase is the most serious, both in duration and intensity.

Location and Origin of Strikes.

Although the majority of strikes occur in the breech area, a large proportion are on the back, and they may occur on any part of the body. Strikes originating in the breech may extend over the tail-head on to the rump, or on to the hind-leg and even flank, their original focus becoming practically deserted, so that the origin of a strike in the hindquarters area may be uncertain. In Table I the strikes on which informa-

TABLE I.

Location	Strikes	Percentage of total	Proportion originating in "clean" wool	Distribution of Farm Cases
Hindquarters and Flanks ...	648	66	33%	140 (43%)
Loins and Back	208	21	77%	78 (24%)
Shoulders	93	9	89%	88 (27%)
Other Areas	38	4	63%	15 (5%)
Total	987	100	49%	321

tion was obtained are grouped into four categories. Two-thirds of the total occurred in the general region of the hindquarters, and nearly two-thirds of the remainder on the loins and back. The shoulders, in view of their limited area, show a surprisingly high incidence, accounting for the majority of the remaining cases. Of the remaining areas on which strike occurred, the neck and throat was a common site for strike in North and West Scotland (see also MacLeod, 1937a), but not reported elsewhere, except for two instances in North Wales.

In the last column of the table the distribution of the Research Farm cases is given. The sheep were lowland breeds or mixed lowland crosses, except for a limited number of "half-breds" -Cheviot/Border Leicester crosses. The preponderance of body strikes over breech strikes, and the relative frequency of shoulder strikes, are interesting.

TABLE II.
Regional Anomalies.

Mean	Total No. of Cases	Hind-quarters	Back	Shoulders	Misc.
...	...	66%	21%	9%	4%
North, West and Central Scotland	169	-15	+6	+1	+7
N.E. and Central Lowlands and Tweed Basin	160	+13	-7	-1	-3
Solway and Cumbria	122	+6	-2	-4	0
Remainder of England	226	+2	+4	-3	-3
N. Wales	162	-5	-1	+5	+1
S. Wales	51	+8	-11	+7	-4
Ireland	93	-7	+3	+6	-1

The deviations from this overall distribution in different regions of the country are given in Table II, which expresses the regional difference for each category of strike as positive or negative anomalies from the mean percentage distribution. The table brings out the frequency of shoulder strikes in Wales and Ireland. It is an interesting point that S. Wales has actually a positive anomaly for shoulder strike, in spite of the excessive proportion of breech strikes (8 out of 13 body strikes were on the shoulder). Similarly, in Lowland Scotland and the Border Uplands, although there is a positive anomaly for breech strikes, the complementary reduction in shoulder strikes is disproportionately low. The incidence of neck, throat and head strikes in Western Scotland (grouped as miscellaneous), and the relatively high frequency of loin and back strikes, are also shown.

Farmers were asked to indicate whether the strike originated in apparently clean wool, in wool soiled by dung or other extraneous matter, on an old strike, or on a wound. The proportion of the strikes originating in apparently clean wool, in each of the four categories, is given in Table I. The absence of apparent cause of strike in the shoulder area, in view of its susceptibility, is of interest.

RELATION OF STRIKE TO HOST TYPE.

Breed and Incidence.

Table III gives the total incidence in each breed for the British Isles. Unfortunately, I have been unable to obtain corresponding figures for the numbers of each breed, but,

TABLE III.

Hill Breeds	Longwool Breeds	Shortwool Breeds
Blackface 290	Border Leicester ... 12	Suffolk... .. 22
Welsh Mountain ... 162	Devon Longwool and 28	Shropshire 14
	South Devon	Hampshire 9
Herdwick and Swale- dale 60	Kent 9	Southdown, Dorset and Oxford 10
Cheviot 38	Roscommon 12	Devon Close wool ... 11
Exmoor and Dartmoor 7		Ryeland 6
		Kerry Hill, Lincoln & Clun Forest 10
Total 557	Total 61	Total 82
Hill x Lowland Crosses 104	Crossbred Lowland	Types 217

through the kindness of Mr. More of the Agricultural Department of Edinburgh University, the figures for adult sheep in Scotland, based on the 1931 census, have been made available. These were given for the separate agricultural divisions, but the numbers of adult Scottish sheep in each division from which samples were obtained are too small to allow of their separate examination; in Table IV the combined Scottish results (adults) are compared with those to be expected on the basis of strike occurring randomly in the breeds. There is a very marked discrepancy in the results, but the distribution of the samples received was so very far from representative of the sheep population (*cf.* Table II of previous paper) that this result may

TABLE IV.

	B.F.	Cheviot	Halfbreds and Grey-faces	Other Breeds and Crosses	Total
1931 Estimate ...	2,315,000	1,361,000	644,500	171,000	4,491,500
Observed cases...	174	19	13	2	208
Expected ...	107	63	30	8	208
Contributions to λ^2 ...	42	31	9.6		

be very largely fictitious. The distribution of blackface cases, however, is, except in the N.E. division, reasonably representative of the major divisions :—

Division	N. & N.W.	N.E.	E.C.	S.E.	W. & S.W.
Thousands of adult B.F.s	328	186	507	183	1,111
Cases in adult B.F.s. ...	23	3	32	20	84

The very large contribution to λ^2 of adult blackfaces may, therefore, be indicative of a greater strike incidence in this breed, relative to other breeds, than might be expected from the numbers alone.

Age Incidence in Different Classes.

The proportion of adult and lamb strikes, for mountain and lowland breeds and their crosses, in the reported cases, is shown in Table V.

In the lowland pure breeds, the long-wool breeds approximated most closely to the mountain breeds (39 adults, 22 lambs), while the shortwools showed a higher proportion of lamb strikes (39 to 43). The high lamb incidence in the crosses is, of course, due to the numerical disproportion of adult and lamb crosses, since most of the crosses are fattened for slaughter, and relatively few kept for breeding.

TABLE V.

	Adults	Lambs	Ratio
Mountain breeds ...	388	169	2.3 : 1
Lowland pure breeds ...	78	65	1.2 : 1
Lowland crosses ...	35	182	1 : 5.2
Mountain and Lowland crosses ...	37	67	1 : 1.8
Total ...	538	483	1.1 : 1

Age and Location of Strike.

The ratio of hindquarter to body strikes, in adults and lambs of the different breed groups, is given in Table VI. In the three main group totals—mountain, lowland and mountain x lowland cross—there is a higher frequency of breech strikes in the

lambs than in the adults. In the combined totals the ratio in each of these three groups is approximately 3:2; this ratio does not agree with that of the Research Farm results, where all strikes were recorded, and where breech strikes totalled only 43 per cent.

TABLE VI.
(Ratio=*Hindquarters/Body*).

Group	Adult	Lamb	Total
Mountain breeds	223/165	112/57	335/222
Mountain x Lowland crosses	14/23	48/19	62/42
Longwool breeds	13/26	12/10	25/36
Down breeds	13/13	13/16	26/29
Other Shortwool breeds	6/7	11/3	17/10
Lowland crosses	20/15	131/51	151/66
Total Lowland sheep	52/61	167/80	219/141

Distribution of Strikes on Shorn and unshorn Sheep.

One might reasonably expect body strikes to be relatively more common on full-fleeced than on shorn sheep. Analysis of the reported cases, however, suggests that the contrary may be the case (Table VII). There is in the table an absolute increase in cases among shorn over those on unshorn sheep with all but the mountain breeds, where the total is unchanged, and a relative increase of body strikes in all groups.

TABLE VII.
(Ratio=*Hindquarters/Body*).

	Unshorn	Shorn
Mountain	124/63	100/86
Longwool	5/6	9/20
Shortwool	9/5	9/16
Mountain x Lowland crosses ...	8/7	4/15
Lowland crosses... ..	11/1	9/5
Total	157/82	131/142
Total except Mountain breeds	33/19	31/56

ALTERNATIVE SPECIES IN RELATION TO HOST AND EDAPHIC FACTORS.

Host Type and Location.

The incidence of species other than *Lucilia sericata*—"alternative species"—in relation to the type of host and to the location of the strike is given in Tables VIII and IX. Table VIII gives the number of cases in which alternative species occurred,

irrespective of whether one or two species occurred in the samples. The table illustrates the following points: (1) The great majority of the alternatives occur in the mountain

TABLE VIII.

	Mountain sheep			Mountain x Lowland crosses			Lowland sheep		
	No. of Cases	No. containing alternatives	Per cent.	No. of Cases	No. containing alternatives	Per cent.	No. of Cases	No. containing alternatives	Per cent.
ADULTS—									
Hindquarters	212	34	16	12	1	8	45	1	2
Body ...	153	51	33	22	2	9	53	1	2
LAMBS—									
Hindquarters	109	20	18	45	3	7	167	5	3
Body ...	51	11	22	17	3	18	74	2	3
COMBINED—									
Hindquarters	321	54	17	57	4	7	212	6	3
Body ...	204	62	30	39	5	13	127	3	2
TOTAL STRIKES	525	116	22	96	9	9	339	9	3

breeds, and their lowland crosses have a higher incidence than the purely lowland sheep. The association here between breed group and incidence of alternatives is statistically of high significance. (2) The alternatives occur more frequently in body strikes than in breech strikes, both in adults and lambs. (3) There appears to be no differential age susceptibility to infestation by alternatives.

In Table IX the incidence of each alternative is given for the individual breeds of mountain sheep. Since two alternative species sometimes occur in the same sample, the totals for alternatives in this table will not agree with those in Table VIII.

TABLE IX.

		Blackface				Welsh			Herdwick and Swaledale				Cheviot		
		Total	L.c.	P tn.	C sp.	Total	L.c.	C sp.	Total	L.c.	P tn.	C sp.	Total	L.c.	P tn.
Adults	Hindquarters ...	114	10	6	3	52	7	—	30	9	1	—	12	—	1
	Body ...	96	32	8	4	36	9	1	12	1	3	—	8	—	1
Lambs	Hindquarters ...	44	8	—	3	46	1	—	10	4	1	3	7	1	—
	Body ...	18	4	—	2	24	2	1	4	1	—	—	5	—	1
Total Strikes		272	54	14	12	158	19	2	56	15	5	3	32	1	3

No *Phormia* occurred among Welsh Mountain sheep, and no *Calliphora* spp. in the cases from Cheviot sheep. Only five adult and two lamb strikes from Exmoor and Dartmoor sheep were reported; no alternative species occurred. The following points may be noted: (1) *L. caesar* type (*i.e.* *L. caesar* and/or *L. illustris*—see previous paper) was relatively more frequent in body than in breech strikes in Blackface and Welsh sheep, but not in the Herdwick and Swaledale cases. (2) *Phormia* occurred principally in the adults—this agreeing with the observed tendency of the species to be an early season striker (see previous paper)—and tended to be relatively more frequent in body strikes in all breeds. (3) *Calliphora* spp. showed no consistent tendency to favour either age or location, occurring indiscriminately and in low incidence.

That there is, in general, no association between incidence of alternatives and the distribution of strike on the body is clearly shown by a comparison of the anomalies, for the Scottish Highlands, Cumbria and North Wales, in the percentage distribution of strikes on the body (Table II). These do not agree either with the observed incidence of alternative species in these regions or with the incidence in the principal breeds for the regions—Scottish Blackface, Herdwick and Swaledale, and Welsh Mountain respectively.

Alternative Species in relation to Pasture Type.

From the records obtained, the types of grazing on which strikes occurred have been divided into three main categories:—

- (1) Fields and permanent pasture.
- (2) Rough grazing, including fenced hill or moor "intakes".
- (3) Open mountain or moor.

The relation of these pasture types to the incidence of alternatives is given in Table X, the results being divided into those for "alternatives areas," *i.e.* north, central and west Scotland, Cumbria and south-west Scotland, and North Wales, and those for the remainder of the British Isles. There is here a clearly significant

TABLE X.

Category				1	2	3
" Alternatives Areas "						
Cases	...	...	...	180	82	182
Alternatives	...	...	...	25	18	80
Percentage Alternatives...				13.9	22	44
Remainder of British Isles						
Cases	...	...	...	395	54	63
Alternatives	...	...	...	20	0	6
Percentage Alternatives...				5.1		9.5
Total						
Cases	...	...	...	575	136	245
Alternatives	...	...	...	45	18	86
Percentage Alternatives ...				7.8	13.2	35

association between the type of pasture and the occurrence of alternative species, the probability of the variables being independent of each other being far beyond the 1 per cent. point.

The material was also examined for association between the type of vegetation on the pasture and incidence of alternatives. For this purpose, the vegetation types were classified as follows:

(1) Good pasture, including crops, leys and good permanent pastures.

(2) Rough grazing.

These two exclude all pastures where gorse, whin, wood, bracken or heather were reported as present.

(3) Grazing with gorse and scrubwood.

(4) Grazing with bracken.

(5) Grazing with heather.

Where heather and bracken and/or gorse occurred together, the strike was credited in replicate to the several categories. Table XI gives the results, the incidence of each alternative species being given separately. Here again there is an obvious and

TABLE XI.

		Good Pasture		Rough Grazing		Gorse and Wood		Bracken		Heather	
		" Alternatives Areas "									
Cases	...	177		86		26		131		94	
L.c....	...	15	9%	17	20%	3	12%	40	31%	26	28%
P. tn.	...	4	2%	4	5%	2	8%	9	7%	8	9%
C. ...	...	2	1%	1	1%	1	4%	9	7%	6	6%
Total	Alts.	21	12%	22	26%	6	23%	58	44%	40	43%
		Other Areas									
Cases	...	395		47		27		34		40	
L.c.	...	14	4%					2	6%	4	10%
P. tn.	...									1	3%
C. ...	...	5	1%								
Total	Alts.	19	5%					2	6%	5	13%
		Total									
Cases	...	572		133		53		165		134	
L.C.	...	29	5%	17	13%	3	6%	42	26%	30	22%
P. tn.	...	4	1%	4	3%	2	4%	9	6%	9	7%
C. ...	...	7	1%	1	1%	1	2%	9	6%	6	5%
Total	...	40	7%	22	17%	6	11%	60	36%	45	34%

L.C. = *L. caesia* type, P. tn. = *P. tetraneura*, C. = *Calliphora* spp.

significant association between vegetation category and incidence of alternatives in general. Pastures with gorse and wood are usually of good quality, superior to the mossy and benty grazings of category 2, and the relative incidence corresponds to this order. It will be noticed that although rough grazings, with or without gorse or scrub-wood, show a marked increase over good pastures, the grazings including bracken and heather form a distinct group, of still higher susceptibility to presence of alternatives. Further analysis of the results shows that both heather and bracken seem to be concerned in this increased tendency, *viz.*, Table XII, where pastures are classified as (1) bracken but no heather, and (2) heather but no bracken, as compared with cases of mixed heather and bracken.

TABLE XII.

			Bracken (no Heather)		Heather (no Bracken)		Heather and Bracken	
			Alter- natives areas	Other areas	Alter- natives areas	Other areas	Alter- natives areas	Other areas
<i>L. sericata</i>	...	...	43	20	24	23	30	12
<i>L. caesar</i>	...	...	24	1	10	3	16	1
<i>P. terraenovae</i>	...	...	5		4	1	4	
<i>Calliphora</i> spp.	...		4		1		5	
Total alts.	...	...	33	1	15	4	25	1

Since there is an obvious relation between grazing types and the vegetation on the grazing, the association between alternatives and, say, vegetation type might be illusory, and due to their common association with certain grazing types. The partial associations of vegetation and alternatives have, therefore, been examined, so far as the nature of the results allowed. Only those results for which information on both pasture type and vegetation type was given have been used. The vegetation was classed as presence or absence of bracken and/or heather (B and b), and the grazings as open hill and moor (H), or enclosed land (h), the latter including the two categories "Fields" and "Rough Grazing." Table XIII gives the results, arranged

TABLE XIII.

			Bracken and/or Heather (B)		No Bracken or Heather (b)	
			Total Cases	Alternatives	Total Cases	Alternatives
Total results	...	H	175	63	65	10
		h	47	7	660	54
Alternatives areas only	{	H	130	58	39	10
		h	33	7	230	34
Remainder of Britain...	{	H	45	5	26	0
		h	14	0	430	20

(H=Open Hill and Moor. h=Enclosed Grazing.)

for (a) all records, (b) records from the "alternatives areas," and (c) records from the remainder of the British Isles. The analysis of the "total records" table is given in detail below; the others have been worked out in the same manner.

N=total cases

H=No. of cases on hill pastures

A=No. of cases with alternatives

B=No. of cases on vegetation with bracken and/or heather

1st Order frequencies

N=947

A=134

H=240

h=707

B=222

2nd Order frequencies

AH=73

Ah=61

AB=70

HB=175

hB=47

3rd Order frequencies

AHB=63

AhB=7

All Cases

$$B/N = 23.5\%$$

$$AB/A = 52.2\%$$

Hill Pastures

$$HB/H = 72.9\%$$

$$AHB/AH = 86.3\%$$

Enclosed Pastures

$$hB/h = 6.7\%$$

$$AhB/Ah = 11.5\%$$

Thus there is a clear association between presence of alternatives and presence of bracken (and/or heather) in both the "hill pastures" and the "enclosed pastures" groups; if the association were due entirely to the association of hill pastures and bracken, the partial association of bracken and alternatives, with pasture type constant, should be negligible.

The analyses for the other two tables are as follows:—

	<i>All Results</i>	<i>Hill Pastures</i>	<i>Enclosed Pastures</i>
Alternatives Areas ...	37.7% and 59.6%	77% and 85.4%	12.5% and 17.1%
Other Areas ...	11.5% and 20%	63.5% and 100%	3.2% and 0%

Thus, in the areas where alternative species occur fairly frequently, there is a partial association, though of low intensity, between alternatives and bracken, and in areas where alternatives are rare, this partial association is again shown in the "hill cases" group. The relative scarcity of alternatives in the enclosed areas is such that the association cannot be examined from the limited records.

Putting into words the results for "hill pastures" (other areas), one might say that: (a) the proportion of hills which had bracken on them (judged from case incidence), was 63.5 per cent., whilst (b) the proportion of "hill" alternatives which occurred in bracken was 100 per cent. If the bracken were not directly associated with alternatives, one would expect only 63.5 per cent. of the "hill" alternatives to occur on bracken grazing, i.e. the increase of proportion indicates a partial association between bracken and alternatives when the results are corrected for effect of "hill."

In the "alternatives areas" analysis a complicating factor is the apparent absence of *Phormia* as a striking species from one of the areas—North Wales. The association of alternatives and bracken in these areas was therefore re-examined, where *Phormia* was excluded from the alternatives, i.e. classed as normal, and also where *Phormia* was regarded as the only alternative, other species being classed as normal.

The results are as follows:—

		<i>B.</i>				<i>b.</i>				
Excluding <i>Phormia</i> ...	H.	130	cases,	50	alternatives.	39	cases,	9	alternatives.	
	h.	33	„	7	„	230	„	30	„	
<i>Phormia</i> only	...	H.	130	„	14	„	39	„	3	„
	h.	33	„	0	„	230	„	6	„	

(Note that since *Phormia* was present along with other alternatives in some cases, the totals do not correspond to the figures given earlier for alternatives in "alternative areas.")

	All Results.	Hill Pastures.	Enclosed Pastures.
Excluding <i>Phormia</i> ...	33.7% and 59.4%	77% and 84.7%	12.5% and 18.9%
<i>Phormia</i> only ...	37.8% and 61%	77% and 82.5%	—

The exclusion of *Phormia* has slightly intensified the association in enclosed pastures. This, coupled with the slight nature of the partial association for *Phormia* alone (hill pastures), suggests the possibility that with this species the bracken association may be largely coincidental. To test this, the partial association with hill pastures was worked out for presence and absence of bracken:—

All Results.	Bracken and/or Heather.	No Bracken or Heather.
39.1% and 74%	80% and 100%	14.5% and 33.3%

There thus appears to be a more intense association between *Phormia* and hill or moor type of pasture than between the species and bracken or heather. This is supported by the suggestion contained in Table XII that *Phormia* is more associated with heather—mountain and moor cover—than with bracken—glens and lower slopes (heather 5 of 47 cases, bracken 5 of 63); the nature of the evidence is such, however, that this cannot be taken as more than a suggestion.

An attempt was made to measure the associations in terms of correlation coefficients, in an endeavour to assess the reliability of the differences. The records were set up in groups of three fourfold tables, as shown below, and, if the association, by χ^2 test, was significant, the correlation coefficient was calculated on Elderton's formula for a fourfold classification in its simplest form:—

$$r = \frac{ad - bc}{\sqrt{(a + b)(c + d)(a + c)(b + d)}}$$

The partial correlation of two of the variables, the third being kept constant, was then calculated from the formula:—

$$r_{xz} = \frac{r_{xz} r_{xy} r_{yz}}{\sqrt{(1 - r_{xy}^2)(1 - r_{yz}^2)}}$$

Since the variables in the fourfold tables are not necessarily dichotomous (*e.g.*, enclosed land merges into hill, bracken may be absent, sparse or plentiful, and so on), the legitimacy of the formula for " r " is open to question, and the correlation coefficient tends to be low. The results, however, should have some comparative value. The procedure is given in detail for the first group (Records for all Britain).

Correlation : *Hill and Alternatives. Bracken and Alternatives. Hill and Bracken.*

H h				B b				H h					
A	73	61	134	A	70	64	134	B	175	47	222		
a	167	646	813	a	152	661	813	b	65	660	725		
240			707	947	222			725	947	240		707	947

P	...	< .01	< .01	< .01
r	...	.2719	.2760	.6804

Partial correlation of bracken and alternatives, hill being constant, (h^R_{ab}) is .129.

The results for the other groups are given below :—

	<i>H and A.</i>	<i>B and A.</i>	<i>H and B.</i>	<i>No. of Cases.</i>
Alternatives areas P	... < .01	< .01	< .01	432
r	2668	.2525	.6481	
	$h^R_{ab} = .1134$	$b^R_{ah} = .1453$		
Alternatives areas P	... < .01	< .01	< .01	432
Excluding <i>Phormia</i> r	2447	.3011	.6481	
	$h^R_{ab} = .1939$			
Remainder of Britain P	3	$c\bar{a} .2$	< .01	515
	<i>i.e.</i> differences not significant.			

Partial correlation of hill and *Phormia* (P), bracken being constant.

	<i>H and P.</i>	<i>B and P.</i>	<i>H and B.</i>	<i>No. of Cases.</i>
P	... < .01	$c\bar{a} .02$	< .01	432
r	1769	.1132	.6481	
	$b^R_{hp} = .1768$			

Discussion.

The analysis of the data for some 1,000 strikes reported from farms throughout Britain during 1938-41, and over 300 cases on the Research Station flocks during 1938-42 brings out some interesting points about strike in general. (1) Although the autumn wave of strike, because of its longer duration, has usually a greater total incidence, yet the intensity—the number of cases per unit period—may be higher during the early summer wave. This can be most clearly seen by taking a fairly uniform area, since the period of maximum incidence may vary from area to area. (2) The greater susceptibility of blackface than of cheviot sheep, which I had previously suggested (1937a) as a result of field observations, and which is contrary to general belief, seems to be borne out by the analysis, but unfortunately the relative susceptibility of other breeds cannot be examined from the data because of lack of information on their

relative numbers in Britain, despite the periodic censuses of farm-stock. (3) In breeding flocks, the number of cases in adult sheep would appear to be greater than in lambs; in flocks where the lambs are being fattened for slaughter this finding will of course not apply. This result is in disagreement with that of Maldwyn Davies (1934) who found in North Wales a much greater incidence in lambs than in adults.

The distribution of strike on the body conforms to present belief; some additional information has been gained. The breech area, if one includes the rump and hind-quarters generally, is the principal area; about two-thirds of the reported strikes occurred here. The class of sheep apparently does not effect this proportion, but the proportion is generally higher in lambs than in adults, and in full fleeced than in shorn sheep. Of the rest of the body, the most susceptible area is the shoulders, judging by the number of cases occurring there in relation to the limited extent of the area. These shoulder strikes are practically all on apparently clean wool (83 out of 93 reported were described as clean). The susceptibility of the shoulder area was noted by Davies & Hobson (1935) and an unsuccessful attempt was made to relate it to suint and/or yolk content (Hobson, 1936). Shoulder strike appears to be more common among lowland breeds and crosses than among hill sheep. Thus, from Table II, the ratios of shoulder strike to strikes elsewhere on the body, excluding hind-quarters, expressed as percentages of the total for each geographical region, are as follows:—

Research Farm (lowland breeds)	27 : 29
South Wales	16 : 10
Ireland	15 : 27
North Wales	14 : 25
Scottish Lowlands (including N.E.) and the Tweed Basin	8 : 15
Scottish Highlands	10 : 38
S.W. Highlands and Cumbria	5 : 23
Remainder of England	6 : 26

Strike on the loins and back is relatively common, but many such cases originate in lesions or in soiled wool. A possible summer lesion is "arsenical dip scald", a dermatitis sometimes resulting in the formation of scabs, which almost always occurs on the loins and midback. Starlings, which rest on the sheep's back, are sometimes blamed by the shepherd for soiling the fleece.

Strikes on the neck are a feature of western Scottish strikes. I previously attributed them (1937a) to the rotting of bracken fronds which get entangled in the neck wool as the sheep force their way through the thick bracken. I have often observed fronds so entangled, particularly in cheviot sheep, and in the case of one neck strike reported, the shepherd remarked on the presence of bracken in the neck wool; yet of the 16 cases reported, 14 were in clean wool, so this cannot be the principal cause. Head strike of horned sheep though relatively common did not figure prominently among the reported cases. One farmer, however, sent in *L. sericata* maggots from a tup which had a history of recurrent strikes between the horns almost weekly, for the last three seasons. The tup was strong and healthy.

The peculiar susceptibility, not only of certain individuals, but even of certain parts of the body, was brought out in the reports of several men; thus, a Loch Tayside farmer mentioned that a ewe was struck, in September, for the first time that season, in exactly the same position as in the previous season, and a farmer from Porlock similarly reported, in August, a ewe struck for the third successive year on the same spot, on clean wool.

The occurrence of species other than *L. sericata*—better described as alternative than as secondary species until more is known about their niche in the sheep myiasis

complex—appears to be associated with a number of factors. In the previous paper (1943), I showed its association with certain geographical regions, which might be called "alternatives areas." The present paper gives evidence of association with mountain breeds, and with hill or moor types of pasture; thus confirming the association with "alternatives areas," which are all mountain or moorland. Some hilly regions, e.g., the "Tweed basin" region, and the South Wales region, are, however, not "alternatives areas," so that one is led to look for some associated factor, usually but not always coincident with the topographic factor. The vegetation type suggests itself, and the evidence adduced does suggest that presence of bracken and/or heather is a significant factor. The association, except perhaps in the case of *P. terraenovae*, seems to be closer between alternative species and bracken-heather vegetation than between them and hill-moor pasture. It does not follow, however, that this is the only significant association, or that it is the true causal one; the most that can be said on the evidence is that bracken and or heather type grazings are associated with the conditions which result in alternative species striking sheep.

The alternatives tend to occur more in body strikes than in breech strikes, and this does not appear to be due to a greater preponderance of body strikes in the breeds subject to attack by alternatives. They are more or less equally common in adult and in lamb strikes, except *P. terraenovae*, which is rare in lambs. This agrees with the observed tendency of the species to be an early season fly (see previous paper, and also MacLeod, 1937b). It is an interesting point in this connexion that the congener species, *P. regina*, which strikes sheep in North America, is also an early season fly, at least in the Southern States (Bishopp & Laake, 1915, Parish & Laake, 1935).

Summary.

The seasonal incidence curve of strike is bimodal, and divisible into four phases, the pre-shearing, the shearing trough, the lamb phase, and the late season adult and lamb phase. About two-thirds of the strikes reported by shepherds occurred in the hindquarters area (this term including the rump and hindlegs). In a lowland flock where all strikes were noted over a five-year period the incidence of hindquarters strikes was much lower (43 per cent.). The shoulders area, in relation to its size, is highly susceptible. It appears to be even more common a site in lowland than in mountain breeds. Rather more than half of the reported cases were in adult sheep, and of these more than half were in shorn sheep. Body strikes were relatively more common in shorn than in woolled sheep. Species other than *L. sericata* (referred to as alternative species) occurred mainly in mountain breeds or their lowland crosses, and more frequently in body than in breech strikes. Alternative species were more or less equally common in adults and in lambs, except *Phormia terraenovae*, which was practically confined to adults. The occurrence of alternative species was significantly associated with the type of grazing, and also with the vegetation type on the grazing: the partial association with vegetation type, with pasture type constant, suggests that presence of bracken and or heather is closely associated with the conditions resulting in alternative species striking sheep.

References.

- BISHOPP, F. C. & LAAKE, E. W. (1915). J. econ. Ent., **8**, p. 466.
 DAVIES, W. M. (1934). Ann. appl. Biol., **21**, p. 267.
 — & HOBSON, R. P. (1935). Ann. appl. Biol., **22**, p. 279.
 HOBSON, R. P. (1936). Ann. appl. Biol., **23**, p. 852.
 MACLEOD, J. (1937a). J. comp. Path., **50**, p. 10.
 — (1937b). Proc. R. ent. Soc. Lond., **12**, p. 127.
 — (1943). Bull. ent. Res., **34**, p. 65.
 PARISH, H. E. & LAAKE, E. W. (1935). J. Parasit., **21**, p. 264.

PHOTOTROPISM IN INSECTS: AN INDICTMENT OF THE LIGHT-TRAP METHOD.

By F. A. SQUIRE.

Department of Agriculture, Sierra Leone.

The attraction of insects to light is proverbial, and allusions to it occur throughout the literature, showing that it has always excited the interest and curiosity of mankind. Yet it has not received the scientific treatment it deserves. Entomologists have, it is true, investigated it in recent years, but with no great success. The reason for their failure is not far to seek. The method adopted in the beginning was, unfortunately, that of the light-trap, which led immediately to a utilitarian and unscientific approach. The literature that ensued so far from elucidating, merely obscured, the true nature of the phenomenon.

This is clearly shown by the fact that in nearly every investigation the method is to expose one or more traps of various design and complexity in fields at night, the catch being counted and classified in the morning. This is quite a harmless hobby and may even be of some use in indicating whether one trap is better than another and, so long as it is used for this purpose, there is no fault to be found with this method. But this is not the case. The prevailing tendency has been to proceed from observations of the catch not merely to conclusions regarding the relative efficacy of light-traps, which would be legitimate, but to deductions concerning the laws and nature of phototropism which is fallacious. Thus, to take a common instance, a species A is caught in considerable numbers while another species B, though known to be present, is not trapped in any quantity, and the conclusion frequently drawn is that A is more strongly photo-positive than B. The objection is that the investigator knows nothing about the density and distribution of the species concerned in the vicinity of the traps; he is, therefore, unable to go beyond the observed fact that his trap took more of A than of B, and is not entitled to draw conclusions regarding the relative photo-positiveness of the two species since one may have been more favourably situated or far more numerous than the other in the field.

But there is a more serious objection. The method tells us very little about the reactions of the insects. From what distance did they come and how quickly? Is it not possible that many came to within a certain distance of the light and no further? Is it not possible, indeed, that species B approached up to a point in greater numbers? These are questions which the method cannot answer.

The third and strongest objection to the method is that it does not take into account the important phenomenon of fatigue. This alone, as will be shown presently, vitiates all the work done with light-traps on phototropism. It is the cause of much confusion and, as the following experiments show, it is a difficulty that must be overcome before any real progress can be made in the study of phototropism.

Convinced of the need of a sounder method, the present writer started experiments in 1939 in the West Indies with laboratory bred material (*Platyedra gossypiella*, Saund.), employing as apparatus four lengths of glass tubing each 2 ft. long and 2 in. in diameter laid end to end on wooden cradles and graduated in inches along the whole length. A light of known constant intensity was placed at one end, and specimen tubes containing a moth each were inserted in turn at the other with the mouth of the specimen tube towards the light. The plug was removed, and the distance travelled by the moth in a given time noted.

The light source presented considerable difficulty. Ultimately two were used: in Experiments 1 and 2 a 5-watt frosted lamp on A.C. 240 V mains; in Experiment 3 a 3-amp. lamp on a six volt accumulator about three-quarters charged.

Results at first proved so erratic in spite of careful and repeated experiments that it seemed useless to persevere with the work. In the species tested some moths were strongly attracted, others repelled, and still others appeared indifferent. It was then decided to introduce the same specimen repeatedly so as to test the apparatus. This revealed that fatigue set in quickly and that the moths lost what I propose to call their *phototropic potential* on exposure to light. Such moths at first appeared indifferent to light and, if further exposed, were repelled by it. Previous results were therefore discarded, and the experiments were repeated with the precaution of keeping the moths in a dark cupboard until they were tested. Moths of the same age were collected during the day and placed in large specimen tubes plugged with cotton wool and labelled. They were fed on dilute molasses. The tubes were stacked in trays and placed in a dark cupboard, whence they were taken singly as required for testing. Following this precaution, results became much less erratic.

EXPERIMENT 1.

To demonstrate the loss of phototropic potential due to exposure to light. Five short-cycle unmated females that emerged between 12 noon and 3 p.m. April 10th were tested on April 11th between 9.30 and 10.15 p.m., and again on April 13th between 8.30 p.m. and 2 a.m. of the 14th. The presentation time was $\frac{1}{2}$ min., and the light source a 5-watt lamp connected with A.C. 240 V mains. The results are given in the following table. The figures represent inches travelled along the tube.

TABLE I.

Specimen	Tests 30-33 hrs. after emergence				Tests 80-86 hrs. after emergence			
	1st Test 9.30 p.m.	2nd Test 9.45 p.m.	3rd Test 10 p.m.	4th Test 10.15 p.m.	1st Test 8.30 p.m.	2nd Test 9.30 p.m.	3rd Test 9.45 p.m.	4th Test 2 a.m.
A... ..	72	0	0	0	40	0	0	0
B... ..	24	24	12	0	15	0	0	0
C... ..	65	0	0	0	45	57	0	17
D... ..	36	0	0	0	32	44	14	65
E... ..	48	24	0	0	51	24	68	33
Means ...	49	9.6	2.4	0	36.6	25	16.4	23

EXPERIMENT 2.

To measure the loss of phototropic potential. Nine short-cycle moths, five females and four males, 48 hours old were first tested, then presented for 15 minutes 1 ft. from the light source and then tested a second time. Light source same as in Experiment 1. Presentation time $\frac{1}{2}$ minute.

TABLE II.

Specimen	Before exposure	After exposure
A. Female	24	0
B. do.	50	24
C. do.	81	0
D. do.	89	0
E. do.	12	0
F. Male	96	13
G. do.	96	0
H. do.	36	0
I. do.	96	0
Means	64.4	4.1

EXPERIMENT 3.

To measure the recovery of phototropic potential. Fifteen short-cycle females two days old arranged in three series of five each. Each series was tested between 9 and 9.30 p.m. and again between 10 and 11 p.m., so as to give an increasing period of rest for the three series, as shown in Table IV. The presentation time was $\frac{1}{2}$ minute and the light source a 3-amp. lamp connected to a 6-volt accumulator about three-quarters charged.

TABLE III.

Number of specimens in each series	Series A 9 p.m.	Series B 9.15 p.m.	Series C 9.30 p.m.	Series A 10 p.m.	Series B 10.30 p.m.	Series C 11 p.m.
1	0	30	7	0	0	0
2	3	48	6	5	0	0
3	56	8	37	24	0	0
4	7	2	37	20	0	29
5	72	24	42	0	41	19
Means	27.6	22.4	25.8	9.8	8.2	9.6

TABLE IV.

Series	Period of rest	Difference	Loss of potential	Difference
A	60 mins.	15 mins.	64 per cent.	0.6
B	75 mins.		63.4 do.	
C	90 mins.	15 mins.	62.8 do.	0.6

Conclusions.

While it is not possible to draw final conclusions from these experiments, it may be permissible to offer a tentative interpretation. All three demonstrate a rapid loss of phototropic potential on exposure to light. Experiment 1 indicates that the phototropic potential when exhausted is at least partially recovered after a period of rest. Experiment 2 gives a measure in specific terms of the loss of phototropic potential. In this case the loss was 93.6 per cent., which proves the untrustworthiness of results obtained by any method which ignores the question of fatigue. The experiment also indicates how a general measure of the loss of phototropic potential in terms of the intensity-presentation product can be arrived at by using several series and presenting them for the same period at different distances from the light source. Unfortunately the work was discontinued before this could be done, but from general observation during the experiments, it appears that the decline in phototropic potential is very rapid at first and tails off gradually. Experiment 3 (Tables III and IV) appears to indicate that the recovery of phototropic potential is proportional to the period of rest, but here again a more extended range is very desirable, and these results must be regarded as of a preliminary nature.

It is quite clear, however, from what has been said, that light-trap observations cannot go beyond themselves and form the basis for inductive reasoning concerning the nature and laws of phototropism, though they may well indicate the comparative efficacy of two or more traps. What the experimenter with light-traps really studies is light-traps by means of phototropism and not phototropism by means of light-traps. The latter can be investigated only by direct observation of the reactions of the whole of a known body of living material, and not by counting the trapped portion of an unknown aggregate. The light-trap tells us very little about the reactions of the trapped individuals and nothing about those that were not trapped.

It is equally plain that the question of fatigue must be taken into account in any method of investigating phototropism. The light-trap method fails to do so and therefore stands indicted as unscientific and the extensive literature which it engendered as worthless.

NEW SPECIES OF COCCOIDEA (HOMOPTERA) FROM MAURITIUS.

By R. MAMET. *Exd.*

The types of the species described below will be deposited in the collection of the British Museum (Natural History), and the paratypes are in my collection.

I wish to acknowledge here the valuable assistance received from Dr. W. J. Hall on many occasions.

***Newsteadia mauritiana*, sp. n.**

Adult female (fig. 1) with waxy dorsal and ventral lamellae short and compact. *Ovisac* short. *Derm* membranous except for appendages and four elongate, transverse and more or less distinctly sclerotised ventral plates in the posterior ventral abdominal region. *Antennae* (fig. 2, *a* and *b*) normally 6-jointed; in one case (type) the antennae have 5 and 6 joints respectively. Basal joint (of 6-jointed antenna) very stout, with a denticular process on the ventral apical edge; second joint more slender than first and a little shorter; third joint nearly as long as first but much more slender; fourth and fifth joints of about equal lengths; terminal joint longest, with a stout seta at its apex. The lengths of the different joints (in type) in microns as follows: I, 262 μ ; II, 155 μ ; III, 170 μ ; IV, 100 μ ; V, 93 μ ; VI, 325 μ ; thus corresponding to the formula: 6, 1, 3, 2, 4, 5. All antennal joints with stout, spiniform setae. In the 5-jointed antenna, the first joint is the longest; the lengths of the different joints in microns as follows: I, 270 μ ; II, 162 μ ; III, 217 μ ; IV, 135 μ ; V, 263 μ ; thus corresponding to the formula: 1, 5, 3, 2, 4. In both 5- and 6-jointed antennae, the second joint bears a conspicuous circular sensory pore on the apical half. *Eye* (fig. 1) conical, highly sclerotised; eyestalk slightly curved; average length, 100 μ ; width at base, 100 μ . *Legs* (figs. 1 and 2, *c*) long and stout; without any tibio-tarsal articulation or any demarcation of the trochanter; with numerous spiniform setae. *Claw* (fig. 2, *d*) slender, slightly curved, without denticle. Tarsal digitules represented by stout spiniform setae which are about one-fifth length of claw; ungual digitules setiform and slender, about one-third length of claw, without knobbed extremity. Trochanter with 4 oval, translucent pores on each face. *Labium* (fig. 2, *e*) obscurely dimerous; average length, 238 μ ; average breadth, 215 μ ; bearing numerous setae on its apical half. *Thoracic spiracles* (fig. 2, *f*) not unusual, with a few quadrilocular pores scattered around their openings; external opening represented as a wavy elongate slit. *Abdominal spiracles* (fig. 2, *g*) very much smaller than thoracic; external opening irregular; in 3 pairs present on the anterior abdominal segments. Only quadrilocular pores (fig. 2, *h*) present on the *derm* (dorsal and ventral); these scattered over the whole body but apparently more numerous in the ventral abdominal region. *Venter* with a transverse band of stout setae anterior to the genital opening and a few others scattered over the body. *Dorsum* with less numerous similar setae. *Body spines* (fig. 2, *i*, *i*₁, *i*₂) in clusters dorsally and ventrally, corresponding with the areas occupied by the waxy secretions (lamellae); the spines bulbous at base and tapering to a blunt point. *Venter* with a well-marked ovisac band (fig. 1) running across the base of abdomen and continued along each side almost to the posterior extremity; enclosed ventral surface of abdomen without spines. *Anal ring* (fig. 2, *j*) small, beaded, with six fairly long and stout setae.

Length (on slide): 1.8–2.3 mm.; breadth (on slide), 1.4–1.7 mm.

Material examined: Three adult females.

Host and locality : On moss growing on rotting wood, in the midst of an indigenous forest. MAURITIUS : Cocotte Mt. (2,463 ft.), 27.xii.1941, one adult female (*type*) ; same locality, 24.i.1942, two adult females (*paratypes*).

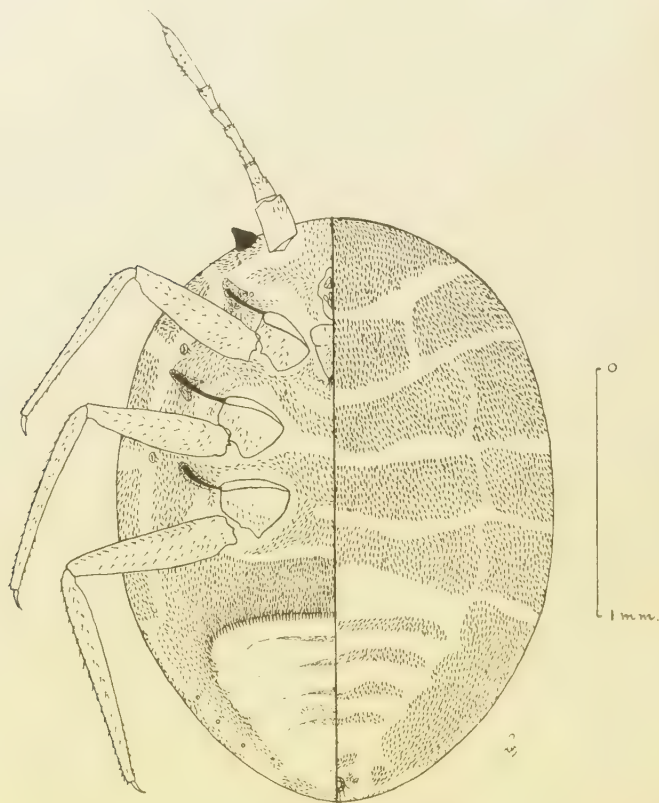


Fig. 1. *Newsteadia mauritiana*, sp. n.—Adult female : body, showing arrangement of dorsal and ventral clusters of spines.

Remarks : Allied to the type of the genus, *N. floccosa*, DeG., from which it differs by the apparently more spinose limbs and antennae, shorter labium, presence of sclerotised transverse abdominal thickenings and three instead of five abdominal spiracles. More closely related to *N. americana*, Morrison, from which it differs by the number of antennal joints, the number of abdominal spiracles, etc.

The following key will help to separate *N. mauritiana* from the other species of the genus (*floccosa* and *americana*). Individuals of these species have not been examined by the author ; descriptive characters are taken from the excellent descriptions and figures given by Morrison in his "Classification of the Scale Insects of the Subfamily Ortheziinae" (1925, J. agric. Res., **30**, pp. 97-154). Other species recorded as belonging to the genus *Newsteadia*, Green, i.e. *tristani*, Silv. (1924, Bol. R. Soc. españ. Hist. nat., **24**, pp. 174-176, figs. vii-ix) and *myersi*, Green (1924, Bull. ent. Res., **19**, pp. 372-373, fig. 4) have not been included in the key. Silvestri

has described *tristani* as *Ortheziola* from Costa Rica, and Morrison (*loc. cit.*, p. 151) states that after carefully examining the "extended description given by Doctor Silvestri, it is possible to reassign this form as the immature stage of some species of

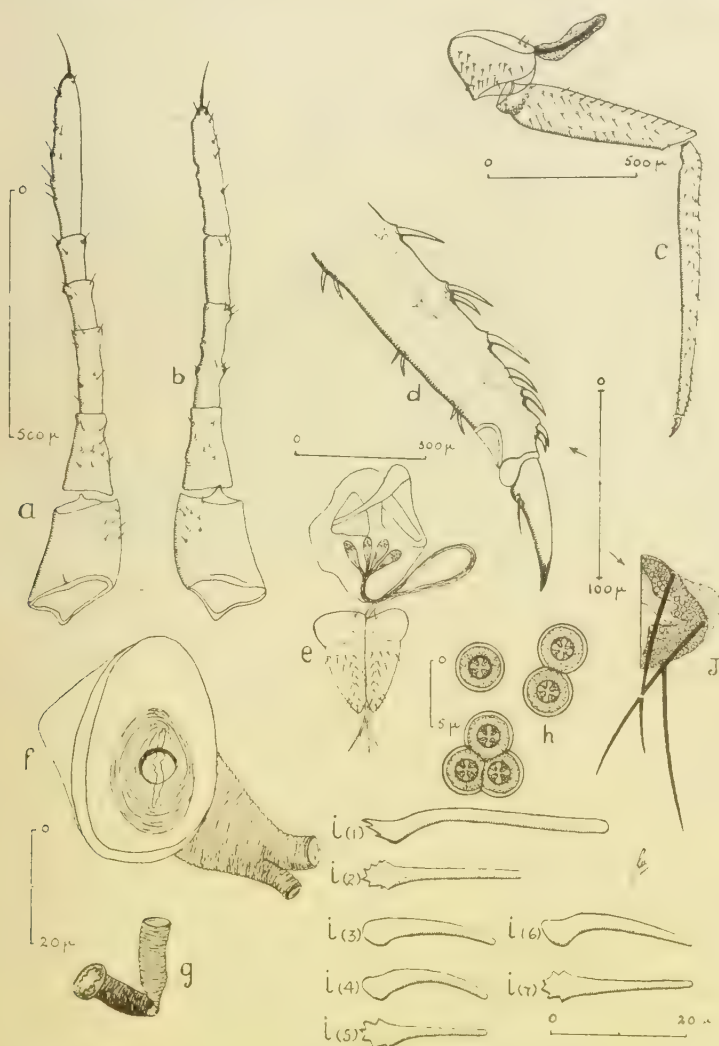


Fig. 2. *Newsteadia mauritiana*, sp. n.—Adult female: *a*, 6-jointed antenna; *b*, 5-jointed antenna; *c*, hind leg; *d*, enlarged portion of hind leg showing claw; *e*, labium; *f*, thoracic spiracle; *g*, abdominal spiracle; *h*, types of quadrilocular pores; *i*₁, spine from ovisac band (first row); *i*₂, spine from ovisac band (second row); *i*₃ and *i*₄, spines from region between the hind pair of legs; *i*₅, spine from ventral region; *i*₆ and *i*₇, spines from dorsal region; *j*, anal ring.

the genus *Newsteadia*." As to *myersi*, described from New Zealand, it is doubtful that it represents a true *Newsteadia* on account of the absence of abdominal spiracles and the presence of "an incomplete transverse crease" across the middle of the second antennal joint. In both characters, *myersi* appears to be more related to *Ortheziola*, Šulc, than to *Newsteadia*, though the number of antennal joints will separate it from *Ortheziola*.

Key to Species of the Genus *Newsteadia*

(Adult Females)

1. Elongate, transverse, sclerotised, ventral thickenings present.....2
Elongate, transverse, sclerotised, ventral thickenings absent...*floccosa*, DeGeer
2. Antennae normally 6-jointed; three pairs of abdominal spiracles; four elongate, transverse, sclerotised, ventral thickenings; ungual digitules setiform and slender.....*mauritiana*, Mamet
Antennae normally 7-jointed; five pairs of abdominal spiracles; only one elongate, transverse, sclerotised ventral thickening present; ungual digitules stout and spiniform.....*americana*, Morrison

N. floccosa has been recorded from Europe (Bohemia, England, France, Germany, Scotland and Sweden) and Australia. *N. americana* has been recorded from Canada and North America.

***Pedrococcus simplex*, sp. n.**

Adult female (fig. 3, *a*) oval in outline, somewhat convex, whitish, coated with a white powdery waxy secretion. Abdominal segments fairly indicated, not produced laterally. *Antennae* 6- to 8-jointed (fig. 3, *b, c, d*); all the joints with several longish slender setae; terminal joint elongate and longest. Distance between antennal bases approximately equal to length of antenna. *Eyes* distinct, sclerotised. *Mouth-parts* fairly developed; mentum dimerous; rostral loop long, extending beyond the insertion of the third pair of legs. Anterior and posterior *spiracles* normal, without parastigmatic pores. *Limbs* (fig. 3, *e*) fairly developed; each segment furnished with several longish, slender setae. Tarsus (of hind leg) shorter than tibia, being about half its length, whilst tibia is shorter than femur. Tibia+tarsus nearly equal in length to femur+trochanter. Tibia with fairly numerous translucent pores and a pair of stout spur-like setae at the distal extremity of inner side. Femur with a few translucent pores. Claw falcate, acute, without denticle. Ungual and tarsal digitules with knobbed extremities; ungual digitules nearly as long as claw, tarsal digitules more slender, a little longer than unguals. *Paranal lobes* (fig. 3, *f*) broadly rounded, fairly sclerotised on both dorsal and ventral surfaces. Each lobe furnished dorsally with a pair of conical spines, six short setae and a few trilocular pores which are not concentrated around the spines; ventrally, there is a long seta, the paranal lobe seta, arising from below the apex of the paranal lobe and accompanied by 7 to 10 much shorter auxiliary setae. *Anal ring* with six setae and the usual double row of beads of the ordinary types. *Anal ring setae* nearly as long as paranal lobe setae. There are no true *cerarii*, but a marginal series of sixteen groups of 1 to 3 conical spines of varying sizes on each side of the body. *Dorsal dermis* with trilocular pores, sparsely distributed stout and short setae and few stout conical spines, arranged as in figure 3, *a*. These spines are situated on faintly sclerotised, small prominences and vary considerably in size. Each spine is accompanied by 4-7 trilocular pores. *Ventral dermis* with trilocular pores, a few pores with subcutaneous ducts present singly on the margin of all abdominal segments and a few large discoid pores situated in the vulvar region. *Ventral setae* longer, more slender and more numerous than those on dorsum, especially in the frontal region where they are longer than anywhere else on venter. Posterior and anterior *ostioles* present. *Ventral cicatrice* (circulus) not found.

Length (on slide) : 2.2-2.4 mm. ; breadth (on slide), 1.6-1.8 mm.

Material examined : Eight adult females.

Host and locality : On roots of an indigenous tree. MAURITIUS : Cocotte Mt. (2,463 ft.), 27.xii.1941 (J. Vinson & R. Mamet).

Remarks : This species differs from all other species of the genus by the fewer number of dorsal conical spines.

Characterised by the number and size of the dorsal conical spines.

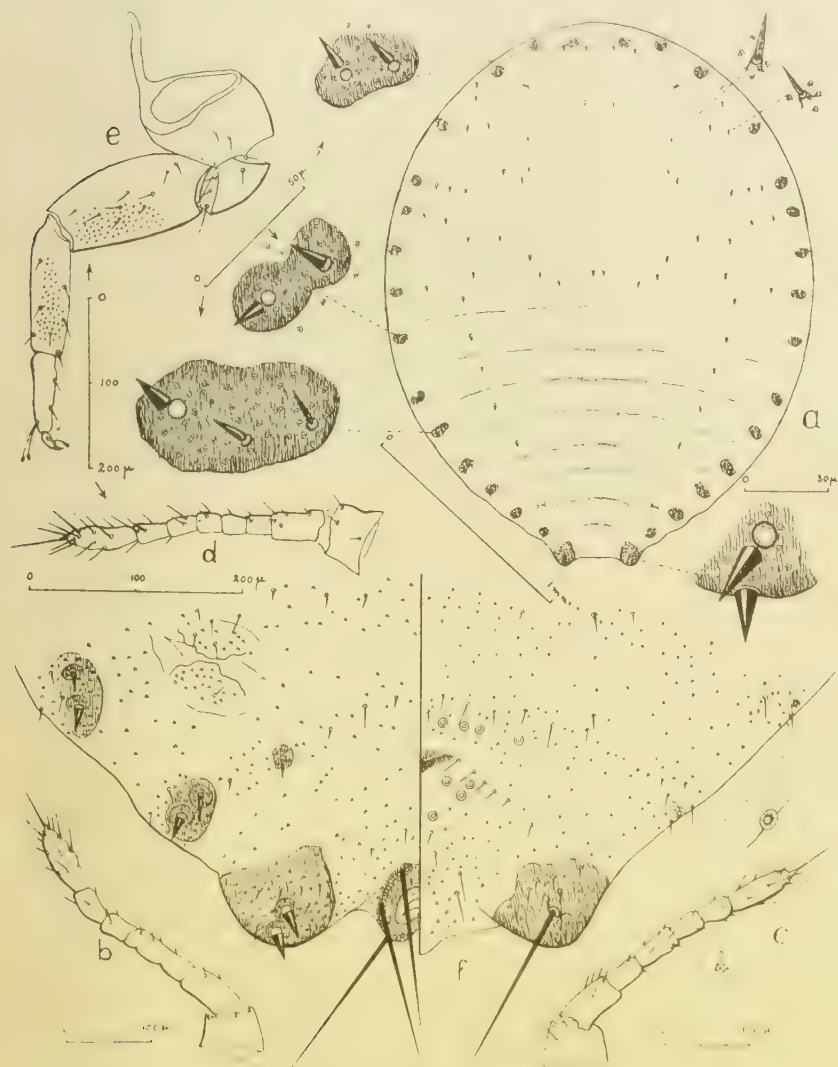


Fig. 3. *Pedrococcus simplex*, sp. n.—Adult female : a, adult female showing arrangement of dorsal conical spines ; b, 6-jointed antenna ; c, 7-jointed antenna ; d, 8-jointed antenna ; e, hind leg ; f, posterior extremity.

***Pseudococcus portiludovici*, sp. n.**

Adult female broadly ovate; older examples approximately circular. Secretory matter pure white, thick. Tassels not well developed except near posterior extremity where they are approximately twice length of those of frons and thorax. *Antennae* slender, 7- to 8-jointed; generally 8-jointed (fig. 4, *a*). In the 7-jointed antenna, the fourth joint showing a pseudoarticulation. Terminal joint always the longest. *Eyes* well developed and somewhat prominent. *Mouth-parts* well developed. *Limbs* fairly developed and robust. Tarsus (of hind leg) approximately equal to half length of tibia; tibia a little shorter than femur. Tibia+tarsus nearly equal in

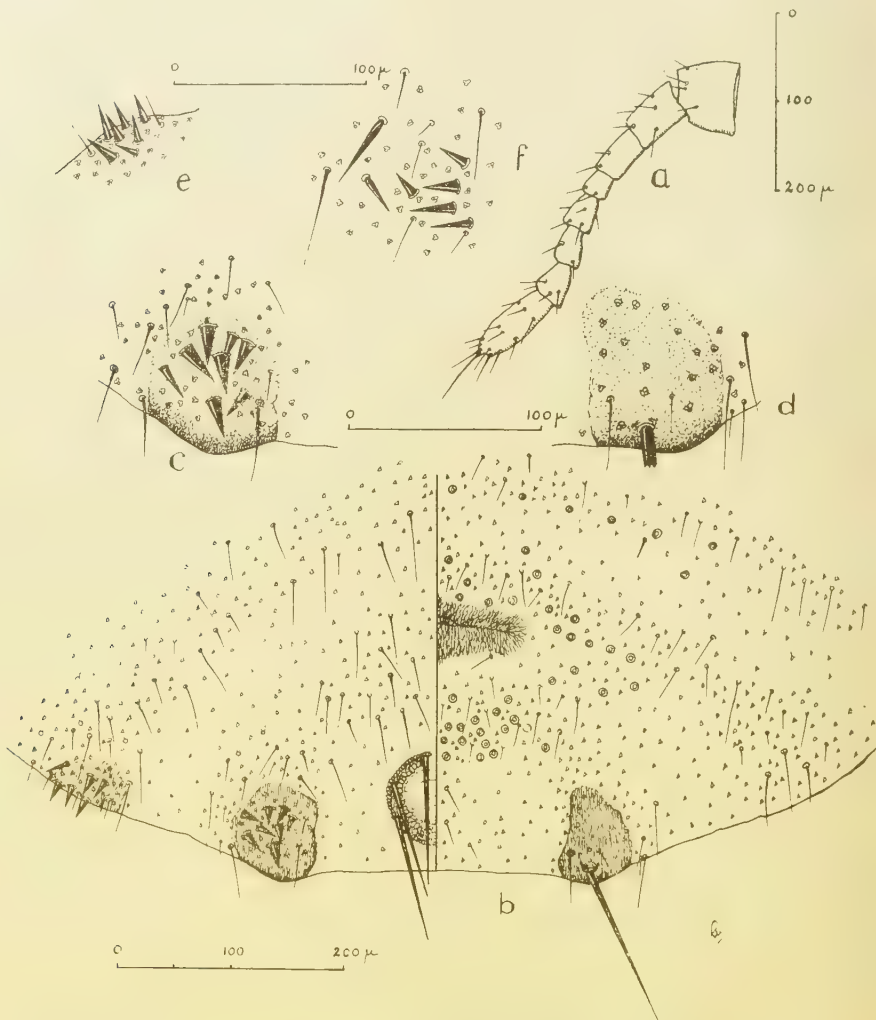


Fig. 4. *Pseudococcus portiludovici*, sp. n.—Adult female: *a*, 8-jointed antenna; *b*, posterior extremity; *c*, paranal lobes (dorsal); *d*, paranal lobe (ventral); *e*, frontal cerarius; *f*, cerarius from abdominal region.

length to femur+trochanter. Distal extremity of tibia with very few, small, translucent pores. Coxa with fairly numerous translucent pores. Claw falcate, without denticle. Tarsal and ungual digitules present and normal. *Posterior extremity* (fig. 4, *b*) broadly rounded. Paranal lobes (fig. 4, *c* and *d*) sclerotised both dorsally and ventrally. Seventeen pairs of *cerarii*, all with stout auxiliary setae which are more numerous, longer and stouter near the posterior extremity of body. No apparent sclerotisation about the *cerarii*, except in the 16th and 17th pairs. There is great variation in regard to the number of cerarian spines, but, in general, the arrangement is as follows: I (frontal), 5-8; II, 4-7; III, 5-8; IV, 5-6; V, 5-7; VI, 6-11; VII, 6-8; VIII, 4-8; IX, 5-7; X, 3-8; XI, 4-7; XII, 5-8; XIII, 5-7; XIV, 5-7; XV, 6-7; XVI, 5-8; XVII, 5-8. The cerarian spines vary much in size but seem to be more developed in the three last abdominal *cerarii*. There is no well-marked concentration of pores around the cerarian spines. *Anal ring* beaded, with 6 setae which are nearly equal in length to the paranal lobe seta. A loose band or cluster of longish, stout setae present immediately anterior to anal ring dorsally. *Dorsal dermis* with numerous trilocular pores, very few, small, roundish pores with short tubular ducts situated near the marginal area of the abdominal segments and numerous longish and slender setae. *Ventral dermis* with numerous trilocular pores, fairly numerous discoid pores surrounding the genital aperture (vulva) and numerous setae which are more profuse on the frontal area and more slender than the dorsal setae. Anterior and posterior dorsal *ostioles* present. *Ventral cicatrice* (circulus) oval to quadrate.

Length (on slide): 2.4-3.2 mm.; breadth (on slide), 1.6-2.6 mm.

Material examined: Eight adult females.

Host and locality: At the base of tender petioles of leaves of *Latania Verschoffeltii*. MAURITIUS: Cassis (Pleasure Ground), District of Port Louis, 18.x.1940.

Remarks: Related to *Pseudococcus leverii*, Green, described from the Solomon Islands (1934, Ann. Mag. nat. Hist., (10) 13, p. 473) by the nature of the *cerarii*. It differs, however, from this species, by the greater number of antennal joints, the longer and stouter limbs and the stouter dorsal setae of the posterior extremity of the adult female.

***Trionymus dactyloctenii*, sp. n.**

Adult female (fig. 5, *a*) elongate, with fairly parallel sides, pinkish, covered with a white, powdery, waxy secretion. Derm membranous. *Antennae* 7- to 8-jointed (fig. 5, *b* and *c*). All joints with several longish setae. Terminal joint elongate and longest. *Mouth-parts* fairly small. *Mentum* (fig. 5, *d*) obscurely dimerous. *Limbs* (fig. 5, *e*) small and slender. *Tarsus* (of hind leg) approximately equal to two-thirds length of tibia; tibia nearly equal in length to femur. Tibia-tarsus a little longer than femur-trochanter. Coxa (fig. 5, *f*) with numerous roundish to oval pores. Claw falcate, without denticle. Tarsal and ungual digitules with knobbed extremities, normal. *Posterior extremity* (fig. 5, *g*) broadly rounded. Paranal lobes not well developed. With but one pair of *cerarii*, these on the paranal lobes and containing two slender, conical spines, a few trilocular pores which are more or less grouped around the cerarian spines and 5 auxiliary setae. *Dorsal dermis* with trilocular pores, pores with short, subcutaneous ducts and fairly stout setae. *Ventral dermis* with trilocular pores, multilocular discoid pores scattered in the abdominal and frontal regions, pores with short, subcutaneous ducts and longish setae. *Anal ring* faintly sclerotised, normal, with the usual double row of beads and six setae which are a little shorter than the paranal lobe setae. Anterior and posterior *ostioles* present. *Ventral cicatrice* (circulus) not found.

Length (on slide): 2.6-2.8 mm., breadth (on slide), 1.0-1.2 mm.

Material examined: Four adult females.

Host and locality: At the nodes of *Dactyloctenium aegyptiacum*. MAURITIUS: Baie du Tombeau, 5.v.1940.

Remarks: Dr. W. J. Hall, to whom I submitted individuals of this species for comparison with his *Ripersia phragmitis* (1923, *Bull. Minist. Agric. Egypt, Tech. Sci. Serv.*, no. 36, p. 10), reports as follows (*in litt.*):—"This is certainly very like my *Ripersia phragmitis*, described from Egypt, in some respects. Your specimens differ in having 7 or 8 segments to the antennae, instead of 6 or 7 (I never saw 8 on any Egyptian specimen). *Phragmitis* is much larger than your species, but, despite



Fig. 5. *Trionymus dactyloctenii*, sp. n.—Adult female: a, outline of adult female; b, 7-jointed antenna; c, 8-jointed antenna; d, mentum; e, hind leg; f, enlarged portion of coxa of hind leg; g, posterior extremity.

this, the legs are no longer, so that relatively they appear very much smaller in *phragmitis*. It may be that your individuals are not fully developed, although at least one appears to be so. Your specimens have the elongate form with parallel sides that I associate with *Trionymus* whereas *phragmitis* is ovate and has not the same form at all . . . The mentum in your individuals is of a rather different shape,

not that I attach great importance to that, but the anal ring, cerarii, dermal characters and translucent pores on the hind limbs are as in *phragmitis*."

***Aclerda thysanolaenae*, sp. n.**

Adult female (fig. 6, *a*) embedded in a white waxy secretion. *Body* of old individuals very heavily sclerotised; in immature specimens, the sclerotisation is confined to the posterior extremity only. *Form* generally elongate oval; in some specimens, the posterior extremity is turned to one side as in *A. distorta*, Green (fig. 6, *b*). There is a great variation in the length and breadth of this species: the largest examples attaining a length of 9.2 mm. and the smallest, 1.6 mm. *Posterior extremity* of body (fig. 6, *c*) strongly furrowed both dorsally and ventrally. Dorsal margin of body beset with an irregular series of numerous, small, blunt-tipped, *tuberculate setae* (fig. 6, *d*) which are constricted towards their base. The series extends around the body except for a narrow area on each side of the anal cleft (fig. 6, *a, e, f*). Mingled with these tuberculate setae are four types of *pores* :—

1. The "pepper box" type (of Teague) which are present on nearly all the abdominal segments (fig. 6, *g*);
2. A few stellate, circular pores with 4-6 loculi which are found on the first abdominal segments (fig. 6, *h*);
3. Minute pores with peculiar, small, tubular ducts present in the submarginal area of the prosomatic region and also scattered throughout the body (fig. 6, *i*);
4. Pores with large tubular ducts (wax ducts) present on the submarginal area of the body (fig. 6, *j*).

Spiracles with small stigmatic plates (fig. 6, *k*). *Anal plate* (fig. 6, *l₁-l₆*) varying greatly in shape but never cleft.

? *Nymph* without appendages. Posterior end of body (fig. 7, *a*) sclerotised, wrinkled. Anal cleft shallow. Margin of body with a more or less double row of tuberculate setae (fig. 7, *b₁-b₃*) of varying shape and form. Mingled with these tuberculate setae are a few large tubular ducts (wax ducts) (fig. 7, *c*). A few minute pores with peculiar small, tubular ducts also present in the prosomatic area. A few stellate pores near the stigmatic region. *Spiracles* (fig. 7, *d*) with narrow stigmatic plates. Length (on slide), 1.3-2.2 mm.

Larva (embryonic) of the type common to the genus (fig. 7, *e, g*).

Material examined: Seventeen adult females, three ? nymphs and one embryonic larva.

Host and locality: Under the sheathing bases of leaves of *Thysanolaena agrostis*. MAURITIUS: Rose Hill, 2.iii.1939 and 17.ix.1941.

Remarks: This species belongs to the group of which *californica*, Ehrhorn (1897, *Canad. Ent.*, **31**, p. 103) can be considered as the type on account of the presence of multilocular, stellate, circular pores. It differs from *californica* by the presence of tuberculate setae in the caudal region and by the shape of these setae. Apart from the presence of these stellate pores, *thysanolaenae* comes near to *sacchari*, Teague (1925, *Ann. ent. Soc. Amer.*, **18**, p. 439) from which it also differs by the shape of the marginal tuberculate setae and the greater number of the same.

The holotype is a young adult female.

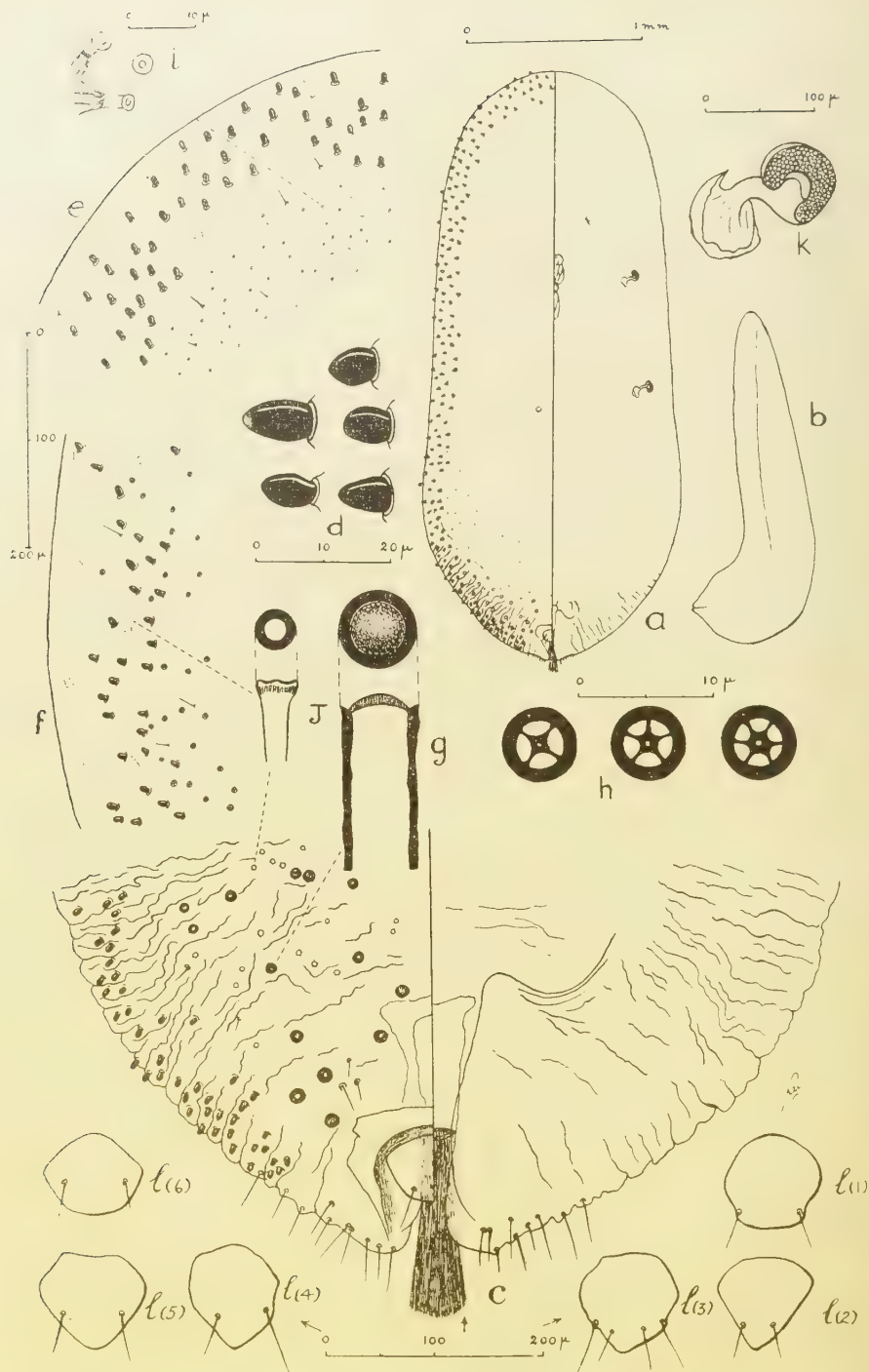


Fig. 6. *Aclerda thysanolaenae*, sp. n.—Adult female: *a*, body, dorsal and ventral; *b*, body, showing posterior extremity turned to one side; *c*, posterior extremity; *d*, tuberculate setae, showing variation; *e*, portion of dorsal dermis from frontal region; *f*, portion of dorsal dermis from abdominal region; *g*, pore of the "pepper box" type; *h*, stellate pores, showing variation in the number of loculi (anterior abdominal segments); *i*, small pores with peculiar tubular ducts (prosomatic region); *j*, pore with large tubular ducts (submarginal region of body); *k*, spiracle; *l*₁–*l*₆, anal plates, showing variation in shape.

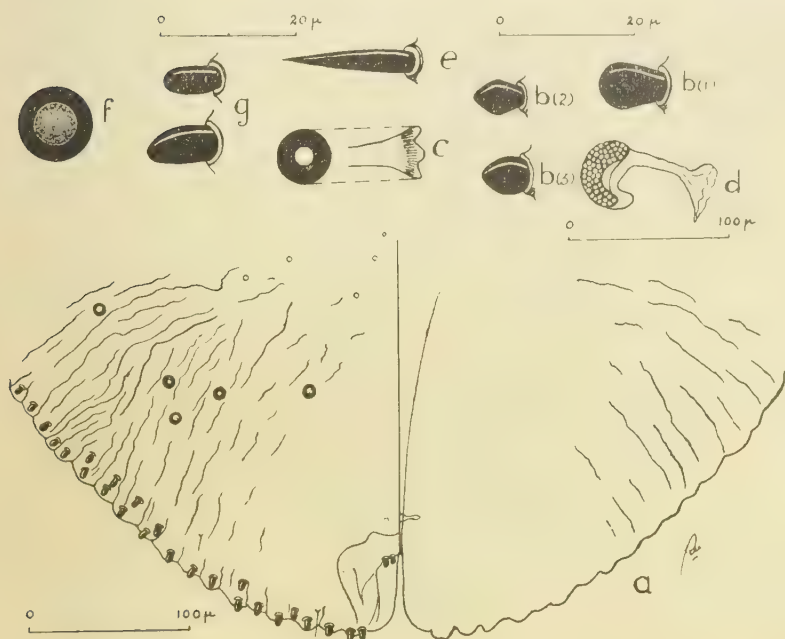


Fig. 7. *Aclerda thysanolaenae*, sp. n.—? Nymph : *a*, posterior extremity ; *b*₁–*b*₃, marginal tuberculate setae ; *c*, pore with large tubular duct ; *d*, spiracle.

Larva (posterior extremity) ; *e*, spine ; *f*, pore of the "pepper box" type ; *g*, tuberculate setae.

Mimusaspis badulae, sp. n.

Female puparium almost linear, straight sided, pale buff in colour. *Larval exuvium* pale yellowish, situated at anterior end of puparium, and beyond nymphal exuvium. *Nymphal exuvium* darker than larval exuvium. Length, 2.5–3.3 mm.; breadth, 0.7–0.9 mm.

Male puparium smaller and paler than that of female.

Adult female long and narrow, broadest across first abdominal segments. Length (on slide), 0.9–1.1 mm.; breadth (on slide), 0.3 mm. Frontal margin with a few minute setae. *Antennal tubercles* with three setae. *Anterior spiracles* with 1–4 parastigmatic pores. Posterior spiracles without pores. *Abdominal segments* well-defined and more or less retracted into one another; the first three segments not produced, the other free segments produced into well developed squames. *Pygidium* (fig. 8, *a*, *b*, and *c*) acutely pointed, with five groups of perivulvar pores. Median group with 2–3, upper laterals with 8–12 and lower laterals with 8–13 pores. One pair of sclerotised, contiguous, non-zygotic and well developed trullae. Second pair obsolete, represented by a sclerotised, serrated incrustation of margin of pygidium. Squames simple; those situated near apex of pygidium much shorter than those on lateral margins. Squames are also present on the lateral margins of all abdominal segments. Large pores with fairly long, tubular ducts situated as follows: one on

margin of 7th abdominal segment and two on margin of 6th segment. Lateral margin of pygidium with very few ducts. Pores are also present on lateral areas of all the free abdominal segments and of thorax. One pair of elongate, knobbed paraphyses in association with median trullae. Anal orifice roundish, small, subcentral.

Material examined: Twelve adult females.

Host and locality: On leaves of *Badula insularis*. MAURITIUS: Macabé forest (2,200 ft.), 2.iii.1940. The male puparia are usually found on the edge of the leaf blade and the female puparia near the midrib.

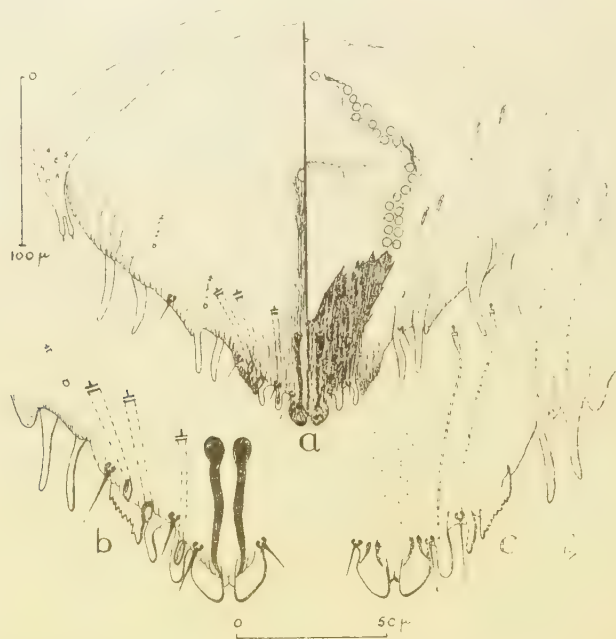


Fig. 8. *Mimusaspis badulae*, sp. n.—Adult female; a, pygidium; b, dorsal margin of pygidium; c, ventral margin of pygidium.

Remarks: Very closely related to *M. mimusopsis*, Mamet, from which it differs by the greater number of perivulvar pores, the presence of 3 macropores on the margin of the 6th and 7th abdominal segments instead of only 2 in *mimusopsis* and the absence of pores near the posterior spiracles.

A NEW AND ECONOMICALLY IMPORTANT SPECIES OF *ANAGYRUS* FROM AFRICA.

By HAROLD COMPERE.

Associate in the Experiment Station, University of California Citrus Experiment Station, Riverside, California.

The species described here, *Anagyrus beneficians*, sp. n., can easily be distinguished from the great majority of species by the colour of the flagellum, which is completely black. Another good diagnostic character that will aid in the identification of this species is the arrangement, in six longitudinal rows, of the coarse dark setae on the frontovertex.

Relatively few species of *Anagyrus* have been described which have the flagellum wholly black. Among these species are: *nigricans*, Perkins, *fusciventris*, Gir.,* *nigriflagellum*, Gir., *subnigricornis*, Ishii, *punctifrons*, Timb., *marquesanus*, Timb., *orbitalis*, Timb., and *longicornis*, Mercet. Specimens of only one of these species are available for study, namely *A. fusciventris*, Gir. The species described as new is very much like *A. fusciventris* in all the major structural characters. Both belong to a group of species characterised by a very short ovipositor. These two species differ in some of their minor characters. In *A. fuscipennis*, the tips of the forewings appear hyaline or silvery, due to a narrow band of refractive cilia at the apex of the blade. In *A. beneficians*, the forewings are uniformly ciliated. The three species described by Timberlake, from the Marquesas Islands, *punctifrons*, *marquesanus*, and *orbitalis*, have the head, thorax, and abdomen black, in colour unlike *A. beneficians*. Likewise, the species described by Girault, from Australia, *A. nigriflagellum*, differs in coloration, the head and thorax are orange yellow. In *A. nigricans*, the apex of the pedicel is reddish, while in the new species it is wholly black. In *A. subnigricornis*, the scape is marked with white at the base as well as near the apex, and the frontovertex at the anterior ocellus is as wide or slightly wider than the head width, in which respects it is unlike *A. beneficians*. In *A. longicornis*, Mercet, the abdomen is truncate at the apex, the pedicel reddish, and the head and thorax yellow; all of which separate this species from *A. beneficians*. In this brief resumé it is possible that some species have been overlooked which have the flagellum completely black. However, the conditions under which *Anagyrus beneficians* originally existed and its subsequent introduction into Kenya Colony strongly indicate that the species has not been described previously.

Anagyrus beneficians, sp. n.

Lower portion of face, the cheeks, temples and occiput, black or mostly so. Frontovertex orange or yellow or with brownish suffusions and golden reflections; minutely punctate, and with coarse, dark setae arranged in six more or less well-defined longitudinal rows. The following parts black: collar, concealed part of pronotum, anterior concealed part of mesoscutum, axillae, sides of metanotum, propodeum, abdomen. Vertical sides of scutellum more or less blackish, the centre with a conspicuous elongate, black blotch which is a distinctive character. Exposed part of mesoscutum brownish yellow or orange, the scutellum concolorous except as

* In correspondence, Girault stated that *Anagyrus nigricornis*, Timberlake, is a synonym of *A. fusciventris*, Gir. It is assumed that Girault's opinion in regard to identity of this species is correct. In the collection at hand are paratypes of the species described by Timberlake from Hawaii. These Hawaiian specimens are indistinguishable from other specimens at hand, collected in Australia and the Netherlands East Indies.

mentioned. Sides of pronotum and the mesopleura pale brownish yellow; prepectus rather translucent and whitish. Sternum of mesothorax dusky. Antennae completely black except for white blotches on the inner and outer aspects of the scape near the apex. Legs with extensive but rather indefinite black to dusky markings. Middle femora on dorsal and ventral aspects more or less blackish from end to end, the sides sordid white; front and hind femora with the contrasting colors not so well defined. Tibiae, especially of middle legs, pale brownish yellow and the tarsi concolorous or nearly so; tibiae of front and hind legs somewhat more dusky and the tarsi concolorous.

Head, dorsal aspect, slightly more than twice as wide as long (22:10); frontovertex slightly longer than wide (10:8); ocelli in an equilateral triangle or nearly so; the posterior ocelli about twice their own diameter from the occipital margin, and more than once their own diameter from the eye margins. Eyes coarsely hairy.

Antennal scape widely expanded, a trifle more than twice as long as wide (11:5); pedicel about three times as long as wide and slightly longer than the first funicle joint. All funicle joints of equal length and subequal in width, the progressive increase in width hardly measurable. Club about as long as the preceding two funicle joints and not much wider.

Forewings rather evenly and uniformly ciliated; speculum interrupted by five rows of cilia, the basal cut-off portion separated from the wing margin by two rows of cilia. Marginal vein about thrice as long as wide, and almost twice as long as the postmarginal vein.

Abdomen, after shrinkage, triangular, about as long as the thorax; the dorsum deeply sunken. Ovipositor short, about one-half as long as the abdomen.

Length, 1.5 mm.

♂. General color black. Face marked with brownish yellow laterad of the scrobes. Frontovertex black or with slight intrusions of brownish yellow. Sides of pronotum yellowish. Prepectus sordid white. Antennae entirely blackish. Legs more extensively whitish than in the ♀♀.

Frontovertex slightly wider than long, minutely punctate, and with scattered fine, white setae. Ocelli in an obtuse triangle.

Antennal scape a trifle more than twice as long as wide. Pedicel about one and one-half times as long as wide. First funicle joint slightly the shortest, slightly more than twice as long as wide.

Length, 1.2 mm.

This description is based on two lots of specimens. The first series of specimens was received from Richard Le Pelley, in October 1938. These consisted of 5 ♀♀ and 13 ♂♂, reared from *Pseudococcus kenya*, Le Pelley, collected at Kampala, Uganda, by A. R. Melville, in 1938. The second lot of material, received from Le Pelley in April 1941, consisted of many specimens of both sexes. The specimens of the second lot were propagated on *Pseudococcus kenya*, at the Scott Agricultural Laboratories, Nairobi, Kenya Colony. Of these, 20 ♀♀ and 7 ♂♂ were mounted for study. Two specimens of the lot from Uganda have been selected as the holotype and allotype, and all the others designated as paratypes.

The holotype and allotype are to be deposited in the British Museum of Natural History and paratypes to be deposited in the United States National Museum.

THE ESTABLISHMENT OF A NEW SPECIES OF *ANAGYRUS* IN KENYA.

By RICHARD H. LE PELLEY.

Department of Agriculture, Kenya.

Following the original description of *Anagyrus beneficians*, Compere, a short account of its introduction from Uganda and its establishment in Kenya as one of the parasites employed in the control of *Pseudococcus kenya*, Le Pelley, the severe mealybug pest of coffee and various food crops, will be of interest. It is advisable to make clear that this is not a detailed report on the biological control of this mealybug, but a short account only of the work with this one species.

The parasite was one of a number collected by A. R. Melville during a journey through Uganda in 1938. Shipments of these were received and bred by the writer in Nairobi. Information on the parasite in Uganda will not be given here, except to state that, though it was present in more than one area, it seemed a comparatively unimportant member of the group of parasite species associated with this mealybug. It is one of two species referred to by Melville (*Ann. Rep. Dept. Agriculture Kenya 1938*, 2, p. 40) as follows: "Two of these were not purposely consigned because they appeared to be of no practical importance in the field, but were bred in Nairobi from a few insects appearing in consignments of other species."

At first only three female parasites were available; these oviposited readily, and it then remained to see whether they could be kept alive until a male or males thus produced parthenogenetically would emerge. One female parasite was kept in a refrigerator at about 5°C., but this insect died. The other two were kept in glass tubes and fed with honey at laboratory temperatures. Some of the parasitised mealybugs were placed in an incubator at 26°C., and in this way a few males were produced several days before those bred at laboratory temperatures. From the two remaining females and these males, a second generation consisting of both sexes was produced. At about this time, one male was also received from Uganda, and later a few further insects were received, amounting in all to six females and three males of this species.

Of the nine species of primary parasites from Uganda bred on *Pseudococcus kenya* in Nairobi, *Anagyrus beneficians* was found to be the most prolific. It was reared with very little trouble in tubes, in various types of cages, and in hurricane lamp glasses over growing potatoes, which came to be the standard rearing method for the production of large numbers of parasites for liberation. The potato is planted in sand or soil in a round 50-cigarette tin and kept at first in the dark: the shoot resulting is infested with mealybugs, a wooden stand is fastened to the tin and a hurricane lamp glass fixed to the stand with beeswax and resin, and covered with bolting silk on a wooden ring similarly fixed to the top of the lamp glass. In the last four months of 1938 over 28,000 *Anagyrus beneficians* were produced out of a total of 47,000 of all species. It should be stated that this rearing in the early stages of the work was incidental to the biological work still going on, but was the maximum possible with the labour then available, and indicates in fact that *Anagyrus beneficians* was the most prolific in the conditions.

Since that time it has been reared in fair numbers as shown in the table on p. 132.

These numbers are small compared with the total of over 800,000 parasites of all species liberated during the same period, but this insect is now widely spread and is established in general throughout the whole range of the mealybug in Kenya, which

amounts to several thousand square miles. This area is in the Central Province of Kenya and stretches from Machakos and Nairobi in the south to Meru on the north-eastern side of Mount Kenya in the north. It includes a large part of the coffee districts of the country and very extensive areas of native reserves. The mealybug was a major pest of coffee, a number of native food crops and other plants until the successful establishment of the introduced parasites, which has resulted in a marked reduction in the severity of the pest. A routine of sampling the mealybug at and near all liberation sites has been employed throughout and examination of these samples showed definite proof of establishment of *Anagyrus beneficians* in 1941. Since that time, the parasite has become very widely spread, and a random selection of the results from 30 samples from liberation sites of this species in the coffee areas and areas of native crops, showed recovery of *Anagyrus beneficians* from 24 of the samples. Further, a random selection of 30 samples from sites where this species had never been liberated showed recovery from 23 of the samples. This is a clear indication of the general spread of the parasites in the very large area sampled.

Year	Parasites reared	Number of Liberations	Parasites liberated
1938 (Sept. to Dec.)	28,125	4	9,030
1939	94,386	33	75,768
1940	51,432	21	14,271
1941	41,707	23	16,135
1942	81,278	75	59,525
Totals ...	296,928	156	174,729

Collections of mealybugs have shown it to be present several miles from any liberation site and there are cases where apparently isolated "pockets" of mealybug as much as six miles from the nearest liberation have been found heavily infested with this parasite. Of five species of parasites liberated on a large scale, another species of *Anagyrus* (near *Anagyrus kivuensis*, Compere) has proved the most important, being an extremely powerful parasite capable, by itself, of suppressing a heavy attack of mealybug only six or eight months after liberation, of maintaining itself on a very low population of mealybug, and of rapid spread from the site of liberation. *Anagyrus beneficians* has not proved so powerful, but can and does build up to large numbers so that it becomes an important controlling factor. The exact part played by each parasite in reducing the population of the host is extremely difficult to determine, especially in such a case as this where they are introduced simultaneously. *Anagyrus beneficians* does, however, appear to respond in a different way from the other *Anagyrus*, to minor differences in the habitat, and so can persist, and at times become dominant, even though the more powerful parasite is also present. In the conditions of the native reserves, where the mealybug is widely spread on indigenous trees, shrubs and herbs, and where cultivation is often scattered among this vegetation, *Anagyrus beneficians* has often been found to be the most numerous parasite, while in the more altered conditions of coffee cultivation with large areas under this one crop *Anagyrus* sp., near *kivuensis*, is undoubtedly the dominant one.

This would seem to be a case of the successful occupation of different, but probably closely similar, ecological niches by two parasites of the same genus, and a detailed study of their ecology might be of general interest and value.

Summary.

Anagyrus beneficians, Compere, obtained in small numbers from shipments of other parasites from Uganda, proved to breed readily in the laboratory.

Numbers were reared, liberated and established on mealybug in coffee districts and native reserves in Kenya.

It is one of several parasites responsible for a marked reduction in the severity of the mealybug.

A SYNOPSIS OF THE ETHIOPIAN AND INDO-MALAYAN SPECIES OF *MICROPHANURUS* (SERPHOIDEA, SCELIONIDAE).

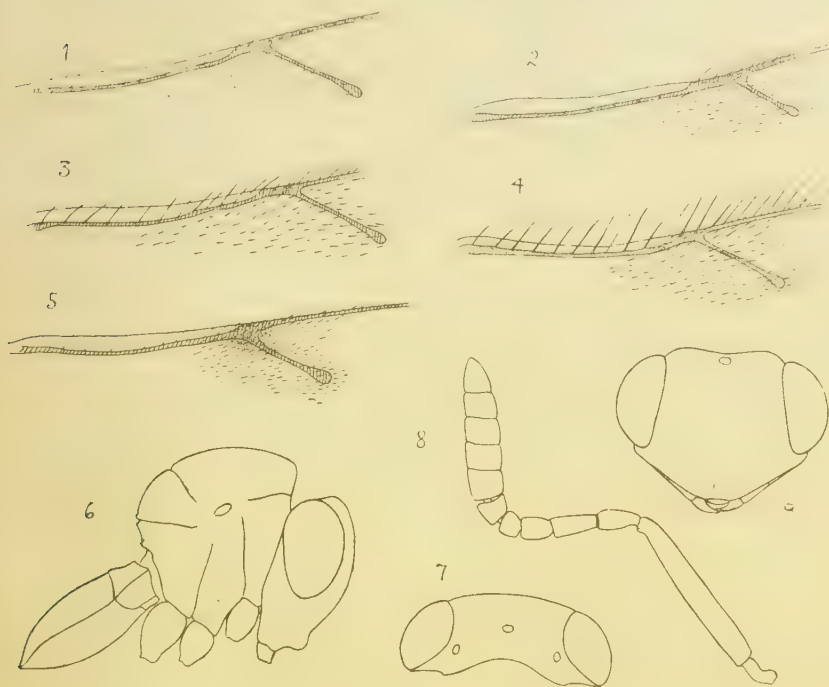
By G. E. J. NIXON, B.A.

Imperial Institute of Entomology. E. 1

This paper brings together all the species of *Microphanurus* from the Ethiopian and Indo-Malayan regions that I have written about during the last eight years. I have found that the fauna of neither region could be studied in isolation if a proper understanding of the taxonomic relationships and host preferences of the genus were aimed at.

The key contains all the species from the regions concerned of which the types or at least authentically named specimens are in the British Museum. Two new African species are described.

For the identification of the Hemipteron, *Atelocera stictica*, Westwood, and for other information I am much indebted to Mr. W. E. China.



Figs. 1-9. 1. *Microphanurus enceladus*, Nixon, part of fore wing, ♀; 2. *M. striaticeps* Dodd, part of fore wing, ♀; 3. *M. maro*, Nixon, part of fore wing, ♀; 4. *M. seychellensis*, Kieffer, part of fore wing, ♀; 5. *M. larides*, sp. n., part of fore wing, ♀; 6. Same, body, lateral, ♀; 7. Same, head, from above, ♀; 8. Same, antenna, ♀; 9. Same, head, from in front, ♀.

SUBFAMILY TELENOMINAE.

Genus *Microphanurus*, Kieffer.

Microphanurus merges gradually into *Telenomus*, Haliday, though as a rule it is not difficult to place a species in one or the other genus. I have accepted the presence or absence of hairs on the eyes as the determinative factor for separating the two genera, *Telenomus* having hairy eyes. This is not, however, always a reliable criterion, for some of the smaller species of *Microphanurus*, such as *crolius*, Nixon (see No. 23), have the eyes feebly hairy. The differences between the two genera will be found summed up in my revision of the African TELENOMINAE (1935, p. 75). So far as is known, *Microphanurus* is essentially parasitic on the eggs of Hemiptera, while *Telenomus* chiefly attacks those of Lepidoptera.

The hosts of about half of the 24 species listed are known. Some of them are important economic pests, such as *Nezara viridula*, L., which is attacked by three species of *Microphanurus*: *basalis*, Woll. (= *megacephalus*, Ashm.), *sipius*, Nixon, and *aloyisii-sabaudiae*, Fouts. It is probable that *M. striaticeps*, Dodd, is also a parasite of the same insect.

M. mahensis, Kieffer, from the Seychelles is not mentioned below, since in my opinion it is a true *Telenomus* in which genus Kieffer originally described it.

Key to the Species (♀♀).

1. Front and middle coxae contiguous, there being no free surface between them. (Upper horizontal surface of frons with a few strong ridges on each side on a shining, smooth ground; mesonotum everywhere with small very even raised reticulations; tergite 2 very characteristically striate-reticulate, the striate element fading out towards apex; stigmalis short (fig. 2)).....
(1) *striaticeps*, Dodd
- Front and middle coxae not contiguous, there being a free, though often narrow, surface of mesosternum between them.....2
2. Mesonotum posteriorly with sharply defined parapsidal furrows, somewhat indistinct in those species which show a considerable amount of longitudinal rugosity posteriorly on mesonotum. (Spp. with the frons somewhat bulging between the lowest point of the eye and the antennal insertions).....3
- Mesonotum posteriorly without a trace of parapsidal furrows.....8
3. Posterior half of mesonotum strongly shining and more or less unsculptured; rugose-punctate on anterior half. (Vertex with an almost completely differentiated ridge, there being traces of micro-sculpture along its actual edge)...
(4) *trophonius*, Nixon
- Mesonotum sculptured all over.....4
4. Margin bounding the eyes behind continued right across the vertex as a completely differentiated, sharp, smooth ridge. (Spp. with the hairs of the subcostalis long, projecting well beyond the edge of the wing (fig. 3)).....5
- This margin at least between the posterior ocelli not completely differentiated, the vertex here being sharply angled or roundly angled.....7
5. Mesonotum with a predominating sculpture of fine scaly-reticulation (shagreened). (Segments 1-3 of the flagellum predominantly brownish).....
(5) *maro*, Nixon
- Mesonotum with strong rugosities which posteriorly become longitudinal.....6

6. Striation of tergite 2 fine, somewhat weak, the intervals smooth and the general surface very shining.....(6) *menecles*, Nixon
 Striation of tergite 2 slightly less fine, the intervals broken and discontinuous so that the sculpture is almost reticulate-striation ; general surface dull.....
 (7) *biblis*, sp. n.
7. Mesonotum, more especially posteriorly, with indications of longitudinal rugosity ; hairs of the subcostalis pale and thin and projecting only slightly beyond the edge of the wing (fig. 1). (Mandible large and wide).....
 (8) *enceladus*, Nixon
 Mesonotum without a trace of longitudinal rugosity, the sculpture consisting of even scaly-reticulation with feebly indicated, very indistinct punctures ; hairs of the subcostalis dark brown, moderately thick and projecting well beyond the edge of the wing. (Mandible small and narrow).....
 (9) *vindicis*, Nixon
8. Segments 2-4 of the flagellum extremely short and strongly transverse, the apex of each closely embracing the base of the next ; segment 1 of the hind tarsus as long as the following segments together. (Antennal club sharply tapering to apex, the apical segment very small).....(3) *mopsus*, Nixon
 These segments much longer and at least 2 not at all transverse ; the segments not thus closely articulated ; segment 1 of the hind tarsus distinctly shorter than the following segments together.....9
9. Radicle of the scape at least $\frac{1}{2}$ as long as the scape. (Spp. with the radicle black ; oblique depression of the mesopleura bounded in front by a strong ridge which extends as far as the middle coxa ; hairs of the subcostalis projecting well beyond the edge of the wing) 10
 Radical of the scape considerably less than $\frac{1}{2}$ the length of the scape.....11
10. Radicle $\frac{1}{2}$ as long as the scape ; surface on each side of the anterior ocellus with strongly raised rugosities on which is superimposed fine scaly-reticulation.....
 (10) *carinifrons*, Cameron
 Radicle $\frac{1}{2}$ as long as the scape ; surface here covered with fine, even scaly-reticulation.....(11) *aloyssi-sabaudiae*, Fouts
11. Scape in a lateral view of the head very distinctly over-reaching the top of the vertex. (Head from in front strongly transverse, elliptical ; flagellum brown throughout, evenly and rather feebly thickened to apex, without a differentiated club ; mesonotum and scutellum strongly flattened and with a fine shagreened sculpture which on the mesonotum is dullest medially ; segment 3 of the hind tarsus only about half as long as 5).....(2) *sipius*, Nixon
 Scape, thus seen, not overreaching the top of the vertex 12
12. Vertex with a completely or almost completely differentiated margin forming a continuation of the postorbital carina.....13
 Vertex without such a carina, at most very sharply angled.....15
13. Frons in greater part smooth and shining ; tergite 2 very slightly longer than wide. (Frons strongly bulging between the lowest point of the eye and the antennal insertions, delicately scaly-reticulate, more especially below, against eye-margin ; on each side of the anterior ocellus a longitudinal row of about 6 sharply defined but very small punctures ; segment 4 of the flagellum almost spherical, clearly nearer in size to 3 than to 5 so that the club is fairly sharply differentiated as 5-segmented ; hairs of the subcostalis very long (fig. 4)).....
 (24) *seychellensis*, Kieffer
 Frons sculptured all over.....14

14. Frons not bulging between the lowest point of the eye and the antennal insertions; sculpture of frons anterior to median ocellus consisting of subscaly-reticulation with a well-marked transverse tendency; oblique depression of the mesopleura margined in front as far as the middle coxa; segment 1 of the flagellum only about twice as long as wide at apex. (Vertex unusually sharply cut away behind the not quite completely differentiated margin, fitting closely on to the thorax like a cap).....(13) *stoicus*, Nixon
- Frons bulging here, its sculpture anterior to the median ocellus consisting of strong rugae; oblique depression of the mesopleura not margined; segment 1 of the flagellum nearly 4 times as long as apically wide.....(12) *barrowi*, Dodd
15. Upper edge of the posterior wall of the middle part of the postscutellum so closely approximated to the posterior margin of the scutellum that the postscutellum bears no transverse or subtriangular rugose area medially; marginalis and base of stigmalis enveloped in a faint cloud.....(14) *larides*, sp. n.
- Structure of the postscutellum different medially, always showing here a transverse or subtriangular, strongly rugose area; marginalis and base of stigmalis without such a cloud.....16
16. Sculpture of mesonotum very fine, consisting of even scaly-reticulation with or without feebly indicated punctures. (Spp. with segment 2 of the hind tarsus not longer than 5; hairs of the subcostalis projecting far beyond the edge of the wing).....group of *suranus*, Nixon. 17
- Sculpture of mesonotum different, at its finest consisting of minute raised points anteriorly and posteriorly with distinct indication of longitudinal rugosity but more usually describable as coarsely rugose or reticulate-rugose.....18
17. Segments 1-4 of the flagellum blackish; segment 2 of the hind tarsus distinctly shorter than 5; tergite 2 with strong striation covering most of its surface.....(16) *sulmo*, Nixon
- Segments 1-4 of the flagellum yellowish; segment 2 of the hind tarsus as long as 5; tergite 2 with only the merest trace of striation mid-basally.....(15) *suranus*, Nixon
18. Oblique depression of the mesopleura not bounded in front by a carina; sculpture of the mesonotum fine, over most of its anterior surface consisting of minute raised points which posteriorly give way to fine striation; small spp. not more than 1 mm. (Hairs of the subcostalis projecting far beyond the edge of the wing).....19
- Oblique depression of the mesopleura bounded in front by a carina; sculpture of the mesonotum much coarser but posteriorly sometimes showing coarse longitudinal rugosity; size larger, at least 1.2 mm.....20
19. Eyes with minute hairs. (Sp. having much of the facies of *Telenomus*).....(23) *crotius*, Nixon
- Eyes without hairs. (Sp. of stouter build than *crotius* and with the head more transverse).....(22) *basalis*, Wollaston
20. Mandible rather small; sculpture of mesonotum very evenly and not particularly coarsely rugose; hind tarsus 2 about twice as long as 5. (No trace of an extra carina on the cheek; hairs of the mesonotum so short and fine that although very numerous they are not at first sight readily visible)(17) *danaus*, Nixon
- Mandible decidedly large, with three teeth as in *danaus* but these long, conspicuous, sharply pointed; mesonotum coarsely rugose; hind tarsus 2 very distinctly less than twice 5. (Usually a well defined carina between that bordering the genal sulcus and the oral margin).....21

21. Mesonotum coarsely rugose-reticulate and with no obvious longitudinal element posteriorly ; hairs of the mesonotum whitish, long, semidecumbent, almost setiform and very conspicuous everywhere ; scutellum somewhat flattened, without a trace of a division into an anterior and posterior area ; mandibles in the closed position forming a mass like two clasped hands and projecting well away from the head (radicle of scape black).....(18) *painei*, Ferrière
- Mesonotum coarsely rugose but without an obvious reticulate element and posteriorly with strong longitudinal rugosity ; hairs of the mesonotum fine, brown, and though numerous not visible everywhere in a dorsal view of the sclerite ; scutellum not at all flattened and with an ill-defined, transverse crest (hardly defined in typical *orontes*) dividing it into an anterior and posterior area ; mandibles in the closed position not presenting the exaggerated appearance of *painei*, though approaching it.....group of *orontes*, Nixon. 22
22. Frons between the anterior and posterior ocellus finely sculptured, without raised rugosity 23
- Frons here with some strong raised rugosities in addition to the fine sculpture. (Crest of the scutellum well developed, though very irregular, the division into two areas well marked ; radicle of the scape yellow)...(21) *priapus*, Nixon
23. Radicle of the scape blackish ; scutellum with hardly a trace of a crest and hence without differentiation into two differently sculptured areas..... (19) *orontes*, Nixon
- Radicle of the scape yellow ; scutellar crest hardly less well developed than in *priapus*.....(20) *orontes*, var. A

1. *Microphanurus striaticeps*, Dodd.

Telenomus striaticeps, Dodd, 1919, Trans. ent. Soc. Lond., **1919**, p. 355.

Microphanurus carinifrons, Fouts, 1934, Mem. Soc. ent. ital., (13) **1**, p. 105, ♂♀.

(Syn. nov.)

Microphanurus striaticeps, Dodd, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 100

Microphanurus striaticeps, Dodd, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 125.

AFRICA : Brit. Sudan, *ex* eggs of *Acanthomia brevirostris*, Stål (Coreidae) and *Agonoscelis versicolor*, F. (Pent.) ; Italian Somaliland (*carinifrons*), *ex* eggs of *Nezara* sp., and also from branch of cotton infested with eggs of *Nezara* ; Nyasaland : Cape Province. INDIA : Punjab (Nixon, 1938).

Fouts' description is very careful and makes it fairly certain that his species is identical with *striaticeps*, Dodd.

2. *Microphanurus sipius*, Nixon.

Microphanurus sipius, Nixon, 1936, Proc. R. ent. Soc. Lond., (B) **5**, p. 133.

AFRICA : Kenya Colony, *ex* eggs of *Nezara viridula*, L.

This is an aberrant species and is only provisionally placed in *Microphanurus*. Its curious flattened appearance and long scape together with the very slender flagellum make it an outstanding species.

3. *Microphanurus mopsus*, Nixon.

Microphanurus mopsus, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 97.

AFRICA : Cape Province ; Abyssinia. Host unknown.

A species having the facies of typical *Microphanurus*, but isolated and most distinctive on account of the structure of the antenna.

4. **Microphanurus trophonius**, Nixon.

Microphanurus trophonius, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 127.

SUMATRA: Asahan, ex eggs of Hemipteron, probably REDUVIIDAE, on *Uncaria Gambir*, Roxb.

By comparison with the other species dealt with in this paper, this is a most distinctive species owing to the absence of sculpture on the posterior half of the mesonotum.

5. **Microphanurus maro**, Nixon.

Microphanurus maro, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, 99.

AFRICA: Cape Province; Natal. Host unknown.

6. **Microphanurus menecles**, Nixon.

Microphanurus menecles, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 98.

AFRICA: Cape Province; Natal. Host unknown.

7. **Microphanurus biblis**, sp. n.

Microphanurus menecles, Nixon, loc. cit. (partim).

This species, which I now describe as new, was formerly recorded by me as *menecles*; it differs from *menecles* as follows:—

♀. Head less transverse and less sharply cut away behind the eyes (in *menecles* it is cut away almost at right angles to the long axis of the body). Mandible much larger and wider, without clearly defined teeth (in *menecles*, the mandible is weakly tridentate). For other differences, see key.

Size larger, 2 mm., approx.

AFRICA: Natal, Kloof, 1,500 ft., ix.1926, 1 ♀, the type (R. E. Turner); Cape Province, Ceres, iii.1925, 1 ♀ (R. E. Turner).

Type in the British Museum.

With its large mandibles, this species is extremely like *enceladus*, Nixon. It differs from this species in having a more or less completely differentiated vertical margin and the pubescence of the wing longer.

8. **Microphanurus enceladus**, Nixon.

Microphanurus enceladus, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 99.

AFRICA: Cape Province. Host unknown.

9. **Microphanurus vindicius**, Nixon.

Microphanurus vindicius, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 128.

JAVA: Mt. Salak; Wonogiri Dist., ex eggs of *Dasynus manihotis*, Blöte (Coreidae).

10. **Microphanurus carinifrons**, Cameron.

Immsia carinifrons, Cameron, 1913, Ind. For. Rec., **4**, p. 105.

Telenomus carinifrons, Cameron, Dodd, 1920, Trans. R. ent. Soc. Lond., **1920**, p. 355.

Microphanurus carinifrons, Cameron, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 138.

INDIA: Dehra Dun. Host unknown.

11. **Microphanurus aloysii-sabaudiae**, Fouts.*Microphanurus aloysii-sabaudiae*, Fouts, 1930, Boll. Soc. ent. ital., **62**, p. 118.*Microphanurus aloysii-sabaudiae*, Fouts, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 102.*Microphanurus artabazus*, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 131. (Syn. nov.)AFRICA: Italian Somaliland, *ex* eggs of *Nezara viridula*, L., and *Acrosternum pallidoconsersa*, Stål; Uganda; Cape Province; Belgian Congo. MALAYA: Setapak (*artabazus*), *ex* eggs of *Scotinophara* sp. (Pentatomidae); Serdang (*artabazus*).11a. **Microphanurus artabazus**, Nixon.

I have already sunk this species above under *aloyssi-sabaudiae*. A careful examination of all the material in the British Museum collections has convinced me that the differences I pointed out in 1938 are not valid. The less convex appearance of the mesonotum of *artabazus* is probably due to mechanical agency and is not equally apparent in all specimens. The more sharply angled vertex of *artabazus* seems at first sight to be significant but I have seen individuals of *aloyssi-sabaudiae* in which the angulation is hardly less well defined.

The wide range of *aloyssi-sabaudiae* as now defined is perhaps disconcerting, but I do not think that locality alone can be accepted as a criterion for specific distinction.

12. **Microphanurus barrowi**, Dodd.*Telenomus barrowi*, Dodd, 1920, Trans. ent. Soc. Lond., **1920**, p. 356.*Microphanurus barrowi*, Dodd, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 137.

INDIA: bred apparently from egg of hawk-moth (Sphingidae).

Only the type female is known. It should not be overlooked that what was taken for the egg of a moth may have been in reality that of a bug.

13. **Microphanurus stoicus**, Nixon.*Microphanurus stoicus*, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 135.MALAYA: Pahang, *ex* eggs of Hemipteron.14. **Microphanurus larides**, sp. n.

♀. Black. Radicle, scape, pedicel and first 4 segments of the flagellum pale brownish yellow. Legs, except the coxae, yellowish.

Head, from in front, triangular (fig. 9). Mandible small, feebly tridentate. Frons over most of its medial part with raised though not strong rugosity, having well marked transverse elements; towards the median ocellus and to the sides of this the surface is finely and evenly scaly-reticulate, without a trace of punctures; no trace of a bulge between the lower, inner margin of the eye and the antennal insertions, the head very strongly transverse as seen from above (fig. 7). Vertex very sharply angled between the posterior ocelli but no trace of a differentiated margin here. Antenna (fig. 8); radicle very short. *Thorax* very strongly convex, raised high above the level of the abdomen and giving the insect a very dumpy appearance (fig. 6). Mesonotum with very fine, close, uneven striation on about posterior half; anteriorly this breaks up into minute raised rugosities; parapsidal furrows absent. Scutellum shining, feebly scaly-reticulate. Postsutellum medially with a transverse, shining plate, which is vertically placed and the upper edge of which is closely approximated to the posterior margin of the scutellum. Oblique shining area of the mesopleura virtually flat, separated from the anterior narrow, feebly rugose area by a weak ridge.

Wings—hairs of the subcostalis thin, inconspicuous, hardly projecting beyond the edge of the wing; stigmalis rather short with a faint cloud enveloping its base; hairs of the wing surface extremely short (fig. 5). Segment 2 of the hind tarsus about $1\frac{1}{3}$ times as long as 5. *Abdomen* slightly wider than its medial length, 5:4. Tergite 1 in greater part smooth and shining; 2 with about 8–12 fine ridges mid-basally extending to about middle; this striation forms a patch which is more or less as long as wide; surface of tergite 2 otherwise smooth, shining; remaining tergites completely hidden beneath 2.

♂. Flagellum pale brownish yellow, rather thick, its pubescence extremely short; segments 4–10 more or less square in outline. Otherwise like the female.

Length: ♂♀, 1 mm., approx.

W. AFRICA: Senegal, Bambey, 4 ♀♀, 1 ♂, bred 31.v.1939 from eggs of *Acrosternum prunasis*, Dallas (Pentatomidae), (*J. Risbec*).

Type in the British Museum.

This is a most distinctive little species, and it seems to have no close allies among the other forms dealt with in this paper. Particularly characteristic of it is the form of the postscutellum by which alone it differs from all the other members of the genus known to me. Other important diagnostic features are the faint cloud at the base of the rather short stigma and the virtual concealment of tergites 3–7 beneath 2.

15. ***Microphanurus suranus***, Nixon.

Microphanurus suranus, Nixon, 1936, Proc. R. ent. Soc. Lond., (B) **5**, p. 132.

AFRICA: Uganda, *ex* eggs of *Antestia lineaticollis*, Stål.

16. ***Microphanurus sulmo***, Nixon.

Microphanurus sulmo, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 126.

CEYLON: Talawakelle, *ex* eggs of *Cantheconidea robusta*, Dist. (Pentatomidae).

This species is extremely closely related to *suranus* but I am satisfied that it is distinct from it on the characters given in the key.

17. ***Microphanurus danaus***, Nixon.

Microphanurus danaus, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 103.

AFRICA: Cape Province. Host unknown.

18. ***Microphanurus painei***, Ferrière.

Microphanurus painei, Ferrière, 1933, Stylops, **2**, p. 108.

Microphanurus painei, F., Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 135.

SOLOMONS: *ex* eggs of *Axiagastus cambelli*, Dist. (Pentatomidae).

See Lever, 1934, for notes on the biology of this species.

19. ***Microphanurus orontes***, Nixon.

Microphanurus orontes, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 102.

AFRICA: Cape Province., Host unknown.

20. ***Microphanurus orontes***, Nixon, var. A.

AFRICA: Tanganyika Territory, Dar-es-Salaam, a series bred from the eggs of *Atelocera stictica*, Westw. (Pentatomidae), (*W. A. Lamborn*).

This series of specimens, now recorded for the first time, bridges the gulf between typical *orontes* and *priapus*, Nixon (No. 21) and calls into question the specific validity of the latter. The structure of the scutellum is more or less intermediate between that of *orontes* and that of *priapus*. More material and further study are needed in order to decide whether we are dealing with a single variable species or with a number of subspecies.

21. **Microphanurus priapus**, Nixon.

Microphanurus priapus, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 133.

JAVA: Buitenzorg, ex eggs of *Chrysocoris atricapillus*, Guér. (Pentatomidae); Wonogiri Dist., ex eggs of *Dasynus manihotis*, Blöte (Coreidae).

Mention of this species has already been made under Number 20.

22. **Microphanurus basalis**, Wollaston.

Telenomus basalis, Woll., 1858, Ann. Mag. nat. Hist., (3) **1**, p. 25.

Telenomus maderensis, Woll., 1858, Ann. Mag. nat. Hist., (3) **1**, p. 25.

Telenomus megacephalus, Ashmead, 1894, J. linn. Soc. Lond., **25**, p. 212.

Liophanurus megacephalus, Ashm., Kieffer, 1926, Das Tierreich, **48**, p. 76.

Telenomus piceipes, Dodd, 1919, Trans. ent. Soc. Lond., **1919**, p. 354.

Microphanurus piceipes, Dodd, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 100.

U.S.A. W. INDIES. MADEIRA. AFRICA: Egypt, ex eggs of *Nezara viridula*, L.; Sudan, ex eggs of *Agonoscelis versicolor*, F. (Pentatomidae); Transvaal, ex eggs of *Nezara viridula*, L.; Cape Province.

See Priesner (1931) for notes on this species and Kamal (1937) for a very full account of its biology.

23. **Microphanurus crotius**, Nixon.

Microphanurus crotius, Nixon, 1936, Proc. R. ent. Soc. Lond., (B) **5**, p. 131.

AFRICA: Uganda, ex egg of Hemipteron, probably COREIDAE.

24. **Microphanurus seychellensis**, Kieffer.

Telenomus seychellensis, Kieffer, 1910, Bull. Soc. ent. France, **1910**, p. 294.

Telenomus truncativentris, Dodd, 1919, Trans. ent. Soc. Lond., **1919**, p. 353.

Microphanurus seychellensis, Kieffer, Nixon, 1935, Trans. R. ent. Soc. Lond., **83**, p. 97.

Microphanurus seychellensis, Kieffer, Nixon, 1938, Ann. Mag. nat. Hist., (11) **2**, p. 125.

SEYCHELLES. AFRICA: Abyssinia; Brit. E. Africa, ex eggs of *Antestia variegata*, Thnb. (Pentatomidae); Tanganyika Terr., ex eggs of *Antestia lineaticollis*, Stål; Uganda, ex eggs of *A. lineaticollis* and *Agonoscelis versicolor*, F. (Pent.); Cape Province. CEYLON: Passara, ex eggs of *Cantheconidea robusta*, Dist. (Pent.).

25. **Microphanurus lemoleae**, Nixon.

Microphanurus lemoleae, Nixon, 1936, Ann. Mag. nat. Hist., (10) **17**, p. 558.

AFRICA: Uganda, ex eggs of Lycaenid butterfly, ? *Spalgis lemolea*, H. H. Druce.

I placed this species originally in *Microphanurus* because of the absence of hairs on the eyes. But taking into account its very small size—55 mm., much smaller than any *Microphanurus* I know—and that it is parasitic on Lepidopterus eggs, I propose to transfer it to *Telenomus* and shall henceforth refer to it as *Telenomus lemoleae*.

*Species Unknown to the Writer.*26. ***Microphanurus africanus***, Fouts.

Microphanurus africanus, Fouts, 1934, Mem. Soc. ent. ital., **13** (1), p. 106, ♂♀.

AFRICA: Italian Somaliland, 1♂, 1♀, "reared from Lepidopterous eggs."

From the description given, this species is certainly correctly placed within *Microphanurus*. The order to which the host-eggs belong may well be questioned.

References.

- DODD, A. P. (1920). Notes on exotic Proctotrupoidea in the British and Oxford University Museums.—Trans. ent. Soc. Lond., **1919**, pp. 321-382.
- FOUTS, R. (1934). Report on a small collection of parasitic Hymenoptera from Italian Somaliland.—Mem. Soc. ent. ital., **13**, pp. 98-109.
- KAMAL, M. (1937). The cotton green bug, *Nezara viridula*, L., and its important egg-parasite, *Microphanurus megacephalus* (Aşhm.).—Bull. Soc. R. ent. Egypte, **21**, pp. 175-207.
- KIEFFER, J. J. (1926). Scelionidae.—Das Tierreich, Lief. 48.
- LEVER, R. A. (1934). Notes on the oviposition habits of two Hymenopterous egg-parasites of *Axiagastus cambelli* Dist. (Pentatomidae).—Proc. R. ent. Soc. Lond., **8**, pp. 139-141.
- NIXON, G. E. J. (1935). A revision of the African Telenominae.—Trans. R. ent. Soc. Lond., **83**, pp. 73-103.
- . (1936). New parasitic Hymenoptera from Africa.—Ann. Mag. nat. Hist., (10) **17**, pp. 558-564.
- . (1936). Three new species of Telenominae.—Proc. R. ent. Soc. Lond., (B) **5**, pp. 131-134.
- . (1938). Asiatic species of *Microphanurus*.—Ann. Mag. nat. Hist., (11) **2**, pp. 122-139.
- PRIESNER, H. (1931). Notes on a Hymenopterous egg-parasite of *Nezara viridula* L.—Bull. Soc. R. ent. Egypte, **15**, pp. 137-139.

AN INVESTIGATION OF THE CHANGES IN A BIN OF STORED WHEAT INFESTED BY INSECTS.

By R. W. HOWE, B.Sc., A.R.C.S., F.R.E.S. *E. M. J.*
Pest Infestation Laboratory, Slough.

Introduction.

The quantitative investigation of the insect population of a mass of grain is a difficult problem which has not, as yet, been adequately attempted. Nevertheless, an understanding of the changes in populations of grain insects is essential at a time when large quantities of grain must be stored. Chernuishev (1939) and Howe & Oxley (in preparation) have suggested methods for obtaining a measure of insect infestation. For effective use of these methods in determining the suitability of grain for storage, it must be possible to judge the effects of the infestation found. Therefore, the opportunity of following the progress of an infestation in a bin of grain was taken, for the information gained should have some general application to practical conditions of grain storage.

Material and Methods.

In May 1941, one and a half tons of Plate (Rosafe) wheat were stored in a galvanised iron bin in a grey, asbestos panelled shed. This quantity of grain completely filled the bin, which was a cube 120 centimetres high with an open top. Against two opposite faces of the bin were similar bins each containing No. 1 Northern Manitoba Wheat, one nearly full, the other half full. Both were slightly infested by *Calandra granaria*, L.

The grain was not examined until November 1941, when it was found to be hot and heavily infested by insects. A detailed examination was made immediately. The grain surface was divided into nine 40 cm. squares, the mid point of each square being used as a sampling point (fig. 1). Air samples, temperatures and grain samples were taken at a number of depths at the sampling points by the methods described

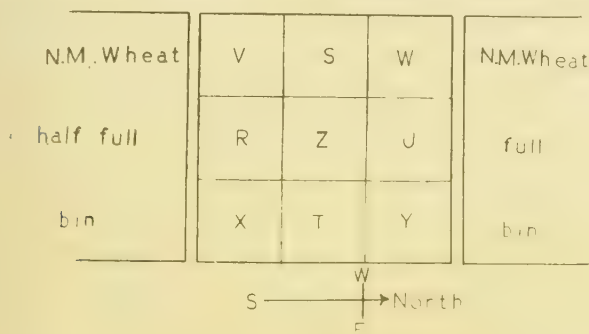


Fig. 1. Plan of bin showing sampling points.

by Oxley & Henderson (in preparation). Some of the grain samples were used to determine water content by the oven drying method ($4\frac{1}{2}$ hours at $115^{\circ}\text{C}.$). From others, weighing approximately 50 g., adult insects were sieved off and counted.

These samples were kept in a constant temperature room at 25°C. and 70 per cent. relative humidity for ten weeks, being sieved twice a week to remove the adults developing from the young stages in the grain. Any free living larvae thus removed (a few *Laemophloeus*) were returned to the samples.

Thereafter, temperatures were taken daily at noon at the points X, Z and W until early January 1942; then monthly until May, and then weekly until October 1942, when the grain was moved. For the point U at the depth of 10 cm., a continuous record from a distant reading thermograph was kept from late November 1941 onwards. A record was kept of the air temperature in a similar position in the adjacent half empty bin. Intergranular air samples were taken from a few positions each month. In February 1942, a thorough investigation of water content was made, and a few samples were determined in the following summer and autumn. Grain samples for population measurement were taken every ten weeks. In January and March 1942, as in November 1941, 50 g. samples were taken at six depths at each sampling point. In May and August 1942, 75 g. samples were taken at these six depths at Y, and from all the sampling points at 25 cm. deep. In October 1942, 75 g. grain samples were taken at 0, 25 and 50 cm. at each sampling point. In July and September 1942, 75 g. grain samples were taken at twelve points chosen using random sampling numbers.

Data obtained.

(a) *The Conditions in early November 1941.*

On 3rd November the grain was found to have heated to 33°C. at 25 cm. depth, although it was cooler than 15°C. at the bottom (fig. 2a). The water content of the

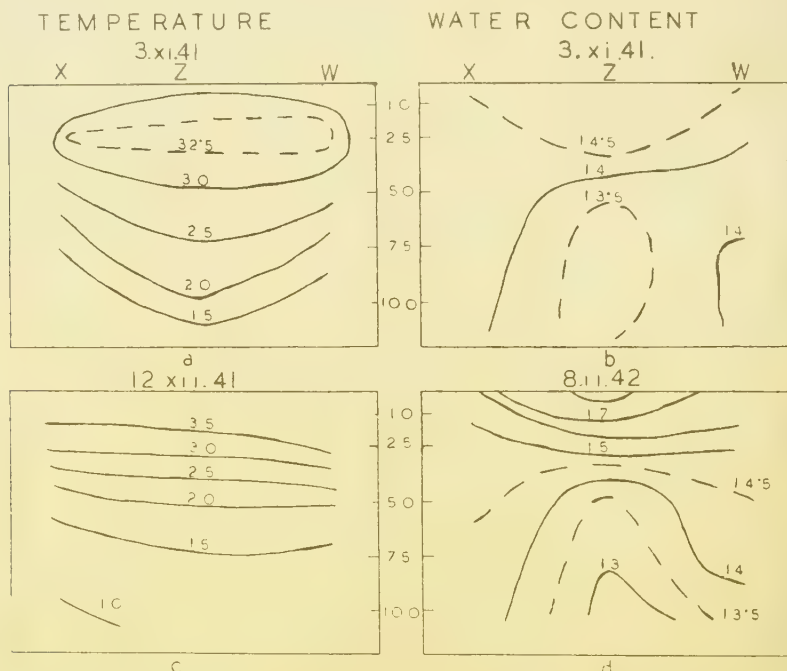


Fig. 2. Temperature and water content data for diagonal XZW (side elevation). (a) Temperature on 3.xi.41. (b) Water content on 3.xi.41. (c) Temperature on 12.xii.41. (d) Water content on 8.ii.42. Lines join points of equal temperature or water content.

grain ranged from 15 per cent. at the surface to 13 per cent. at the bottom (fig. 2b). The carbon dioxide concentration of the intergranular air was over 10 per cent. at 10 cm. depth in the grain.

TABLE I.

Carbon dioxide concentration per cent. in intergranular air, at various depths at the points Z and Y.

Date	Z				Y			
	25 cm.	50 cm.	75 cm.	100 cm.	25 cm.	50 cm.	75 cm.	100 cm.
3.xi.41	14.89	15.55	15.44	15.06	13.66	14.51	14.79	14.69
15.xi.41		14.74						
10.xii.41	16.16	20.41	11.60					
7.i.42	2.63	4.15	4.55					
6.ii.42	2.08	1.19	3.35					
13.iii.42	2.81	4.25	5.02	2.72		5.65		
27.v.42	7.92	8.90	12.07		9.50	11.89	12.16	
18.viii.42	6.55				8.60	12.78	13.49	11.94
14.ix.42	5.16				7.20	9.47	9.48	
13.x.42	2.07	4.19	5.62		4.62	4.52	5.61	

TABLE II.

Number of adults and immature stages of insects found in (50 g. approx.) grain samples taken on 3.xi.41. Totals of nine samples at each depth.

Depth (cm.)	Adults							Immature Stages						
	0	10	25	50	75	100	Total	0	10	25	50	75	100	Total
<i>C. oryzae</i>	179	536	174	77	162	43	1,171	1,125	4,492	2,323	592	540	224	9,296
<i>C. granaria</i>	3	1	1	2	—	—	7	22	13	13	1	3	1	53
<i>Rhizopertha</i>	—	26	24	20	5	2	77	3	116	420	173	60	22	794
<i>Laemophloeus</i>	3	35	35	12	6	—	91	66	1,289	1,357	202	186	94	3,194
<i>Silvanus</i>	—	16	4	2	3	—	25	—	26	16	18	3	3	66
<i>Lariophagus</i>	1	2	1	—	—	—	4	3	25	19	5	1	—	53

An enormous population of insects was present (Table II), mostly the small form of *Calandra oryzae*, L. (Richards, 1943). Smaller numbers of *Rhizopertha dominica*, L., *Laemophloeus* spp. (*L. ferrugineus*, Steph. and *L. minutus*, Ol.), *Silvanus sarrahanus*, L., and a few *C. granaria* and *Lariophagus distinguendus*, Forst., were also present. The majority of adult *C. oryzae* were at 10 cm. depth; larvae of this species and

adults of the others were most numerous at 10 to 25 cm. There were about ten times as many larvae as adults of *C. oryzae* and *Rhizopertha*, and about 35 times as many larvae as adults of *Laemophloeus*. The curves showing the daily emergence of *C. oryzae* from the samples kept at 25°C. (fig. 3), show that the maximum rate of emergence was later in samples taken near the surface than in deeper samples.



Fig. 3. Emergence curves of *C. oryzae*, L., from 50 g. grain samples taken 3.xi.41. Total of the nine samples taken at each depth.

(b) *Fate of the 1941 Infestation.*

During November and December the temperature of the upper layers of the grain rose to 37°C. (fig. 2c), the region of highest temperature being at 10 cm. depth. At the same time the carbon dioxide concentration increased, and reached 20 per cent. at 50 cm. (Table I). On 12th December, when the air temperature was comparatively high for the season (12°C.), very many weevils were found walking over the surface of the grain, many crawling off it. A week later, the grain temperature started

falling, and in a fortnight reached air temperature (fig. 4). The temperature remained below 5°C. until the middle of March, dropping below 2°C. in February. The carbon dioxide concentration fell in February, being less than 3½ per cent. at 75 cm. deep, but began to rise again in March (Table I).

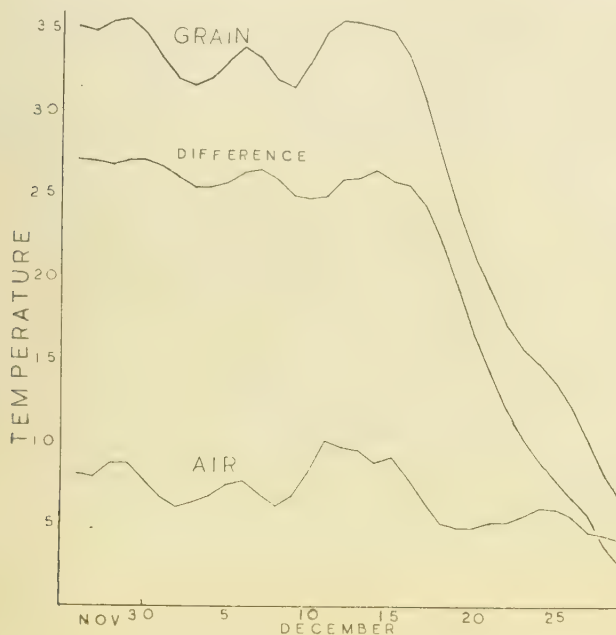


Fig. 4. Graph of floating means of grain temperature at U10, and of air temperature from 26.xi.41 to 29.xii.41. The curve for the difference of these temperatures shows the amount of heating.

TABLE III.

Number of adults and immature stages of insects found in (50 g. approx.) grain samples taken on 8.i.42.
Totals of nine samples at each depth.

Depth (cm.)	Adults							Immature Stages						
	0	10	25	50	75	100	Total	0	10	25	50	75	100	Total
<i>C. oryzae</i>	192	124	28	23	—	1	368	1,055	941	173	35	14	2	2,220
<i>Rhizopertha</i>	34	50	35	12	—	—	131	244	822	522	81	9	4	1,682
<i>Laemophloeus</i>	167	80	121	15	35	5	423	293	1,236	916	69	6	12	2,532
<i>Silvanus</i>	103	210	44	1	2	3	363	16	14	7	—	—	—	37
<i>Lariophagus</i>	1	—	—	—	—	—	1	118	85	11	—	—	—	214

TABLE IV.

Percentage of each species in middle position Z in grain samples taken on 3.xi.41 and 8.i.42. Totals of six depths.

Insect	3.xi.41		8.i.42	
	Total	% at Z	% at Z	Total
Adult <i>C. oryzae</i>	1,171	4.4	37.2	368
Immature „	9,296	10.5	31.4	2,220
Adult <i>Rhizopertha</i>	77	19.5	16.1	131
Immature „	794	18.5	24.4	1,682
Adult <i>Laemophloeus</i>	91	14.3	61.4	423
Immature „	3,194	15.0	23.6	2,532
Adult <i>Silvanus</i>	25	4.0	95.6	363
Immature „	66	7.6	70.3	37

Grain samples taken on 8th January still contained many living larval and adult insects (Table III). Comparison with the November populations (Table IV) showed that the number of *C. oryzae* fell to one-quarter of the November figures. The number of adults of other species, however, had increased, *Laemophloeus* by five times and *Rhizopertha* by twice. *Silvanus* had increased many times, but nearly all of them were found in samples from the 0 and 10 cm. depths in the central position Z (Table IV). The number of larvae of *Rhizopertha* had also doubled, but the larvae of *Laemophloeus* and *Silvanus* were less numerous. Six adults and no larvae of *C. granaria* were recorded. The number of the parasite *Lariophagus* had increased by four times.

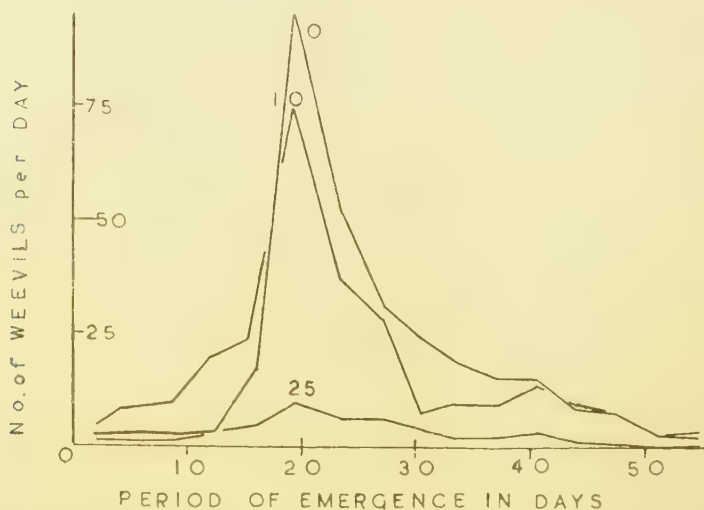


Fig. 5. Emergence curves of *C. oryzae*, L., from 50 g. grain samples taken 8.i.42. Totals of nine samples from each depth. Few insects emerged from 50, 75 and 100 cm.

The distribution of *C. oryzae*, *Laemophloeus* and *Silvanus* had changed between November and January so that the middle position Z was the most densely populated (Table IV). The region of maximum density of population of all species was nearer the surface (Table III). The curves of emergence of *C. oryzae* from the January samples (fig. 5) reach a maximum early in the breeding out period (indicating a high average larval age throughout) and at the same time for all depths.

March samples contained eight adult *Laemophloeus*, one *C. oryzae*, one *C. granaria* and one *Enicmus minutus*, F. In addition, two *Laemophloeus*, two *Lariophagus* and one *Ptinus tectus*, Boield., were bred from these samples.

In February the water content of the grain had increased at the surface to 18 per cent., whilst the sides were also a little wetter than in November (fig. 2d). The centre of the mass of grain was unchanged. The surface dried again to 14 per cent. by August 1942 and then began getting wetter (16 per cent.) by October.

(c) The 1942 Infestation.

During 1942, the surface 25 cm. layer of grain warmed to 16°C. in April, and gradually continued to heat until the temperature exceeded 20°C. early in June. In August, a maximum temperature of 27°C. was reached, but by the end of September the temperature fell below 20°C. once more. The carbon dioxide concentration of the intergranular air at 50 cm. increased to about 10 per cent. in August and then decreased again in September (Table I).

Grain samples from more than 50 cm. deep contained no insects. Table V shows the number of adult and immature insects taken in the May, August and October

TABLE V.

Insects present in (75 g. approx.) grain samples taken in 1942. Totals of nine samples.

Insect	Date	27.v.		8.viii.		15.x.			
		Depth		25 cm.		.0 cm.	25 cm.		50 cm.
		Stage		Ad.	Im.	Ad.	Im.	Ad.	Im.
<i>C. granaria</i>	...	...	...	16	118	82	179	10	139
<i>Laemophloeus</i>	...	...	...	6	38	52	155	75	48
<i>Lariophagus</i>	...	...	...	—	—	5	431	7	342
								4	426
								1	130

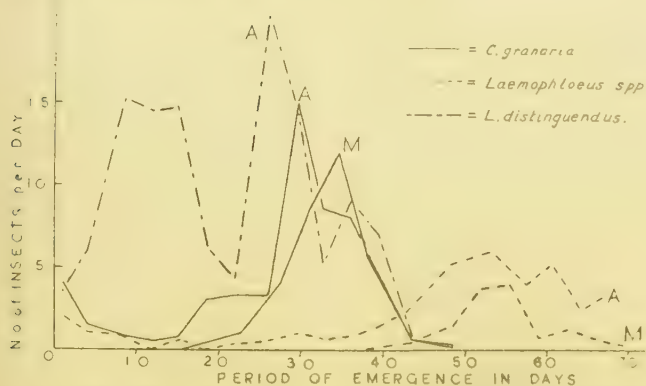


Fig. 6. Emergence curves of *C. granaria*, L., *Laemophloeus* spp., and *Lariophagus distinguendus*, Först., from 75 g. samples taken 27.v.42. (M) and 8.viii.42 (A). Totals of nine samples taken at the depth 25 cm. *Lariophagus* emerged from the May samples.

samples. Many more *C. granaria* and *Laemophloeus* were found in the August than in the May samples. The larvae in the May samples were all young: no weevils emerged in less than 20 days at 25°C. and 70 per cent. R.H. (fig. 6). No *Lariophagus* were found in the May samples, but both adults and young stages were present in the July random samples and all later ones. Large numbers were present in the August and October samples. The October samples showed a change in the distribution of *C. granaria* and *Laemophloeus* both of which had decreased at a depth of 25 cm. By then *Laemophloeus* was more common at 50 cm. and *C. granaria* at the surface than at 25 cm. A few adults of *Silvanus* and *Endrosis lactella*, Schiff., were found in September and October.

Correlation of Results.

(a) General Principles concerned in Heating.

Since the grain under investigation was eventually found to be heavily infested by those species normally associated with Plate wheat, and these insects were not found in either of the adjacent bins, it is reasonable to assume it to have been infested when received, and that the insects were dispersed throughout the bin. At the time of storage, conditions of temperature and grain water content were favourable for insect activity, which in turn produces heat, carbon dioxide and water.

In grain, heat does not readily escape from its point of production, for grain has a low thermal conductivity (Kelly 1940, p. 4). Thus in infested grain heating tends to occur around the infested regions. The amount of heating will depend on the number of insects present, especially of fourth-stage weevil larvae, and on the distance of the heating spot from a cool surface. Thus in an evenly infested pile, the thermal centre of the pile will heat first. The presence of warm spots in a bulk of grain will set up convection currents, which tend to prevent the accumulation of carbon dioxide and to renew the oxygen supply. Translocation of water over short distances will also be favoured (Kiesel *et al.*, 1939), so that hot spots will tend to dry out a little, and grain in the cooler regions nearest to the heating spots will become wetter. Convection currents in a bulk, infested and heating in patches, increase the rate of heat movement upwards from hot spots, hence regions above hot spots become warm and conditions are made more suitable to insect increase. It is interesting to note that Gay & Ratcliffe (1941, p. 178) have some evidence that *Rhizopertha*, an insect with a high optimum temperature, occurred directly over hot spots in warehouse bulks.

(b) Sequence of Events in 1941.

In the bin, heating probably started near the thermal centre (around Z 75) and the convection currents produced passed down the sides of the bin and up the centre, clearing away the carbon dioxide produced. The increased net rate of insect reproduction caused by the rise of temperature at Z 75 probably soon made this region overcrowded. Migration of adult insects into neighbouring areas probably helped to spread the area of heating. This brought the warm region close to the sides of the bin, setting up a horizontal warm layer in place of the original central hot spot. Thus the convection currents in the grain were restricted by the lack of a cool downward path, and carbon dioxide could only escape by diffusion via the top. Had the bin contained any leaks near the bottom, the carbon dioxide would have escaped that way.

It is in the accumulation of the carbon dioxide that this bin differs most from warehouse conditions. For example, a typical heavily infested warehouse bulk heating to 42°C. was found to contain less than 3 per cent. carbon dioxide in the air deep in the bulk.

The insects in the grain, therefore, were modifying their environment by warming the grain and producing a high carbon dioxide tension (probably with a consequent lowering of oxygen tension). Increase of temperature favours insect population growth up to an optimum temperature and then becomes more and more unfavourable. The presence of a high concentration of carbon dioxide is unfavourable. Before October it is unlikely that the temperature of the grain became unsuitable for any of the species of insects present, but the carbon dioxide concentration soon became unfavourable, especially deep in the bin, and this, possibly assisted by other factors, caused the adults to migrate upwards. Nevertheless, the larvae of *C. oryzae* and *Rhizopertha*, which produce a large part of the heat and carbon dioxide, live inside the grains of wheat and so cannot migrate, so that heating and carbon dioxide production continued until the larvae became adults or until their development was slowed or stopped, perhaps resulting in death. Hence there was a movement of population towards the surface resulting in the successive appearance at each depth of (i) adults, (ii) larvae from eggs laid by adults, (iii) heating and accumulation of carbon dioxide. In the depths of the bin the insect population disappeared slowly and so the grain cooled slowly but the carbon dioxide did not escape.

The species of insects would be distributed according to their toleration of carbon dioxide, since in the bin carbon dioxide was the limiting factor. In a warehouse, temperature itself is more likely to become the unfavourable factor for insects in heating grain.

When examined in November, the sequence described was not quite complete. The hottest point was at 25 cm. deep; through November and December it was observed to rise to 10 cm. deep. Surface cooling prevented it moving further, for the air temperature was 25°C. lower than that of the grain at 10 cm. deep. At the beginning of November the temperature was just exceeding the upper limits for *C. oryzae*. *Rhizopertha*, *Laemophloeus* and *Silvanus* have higher optima and conditions were still favourable to the increase of these species. The distribution of insects suggests that *C. oryzae* is not very tolerant of high carbon dioxide concentration, that *Laemophloeus* is more tolerant and *Rhizopertha* the most tolerant (see Tables I, II and III). Comparison of fig. 2a with Table II, and fig. 2c with Table III, shows that the temperature was not excessive at the less populous depths. During November and December the temperature rose too high for *C. oryzae*, which stopped increasing. *Rhizopertha* and *Laemophloeus*, however, more tolerant of high temperatures and carbon dioxide concentration, continued to oviposit and develop. The optimum for *Laemophloeus* was probably eventually exceeded, for the number of larvae in January samples was less than in those of November.

The emergence curves for *C. oryzae* (figs. 3 and 5) illustrate the effect of changes in the bin on this species. At each depth conditions became increasingly favourable for the species and then started to become unfavourable. The favourable period was earlier in deeper positions. Thus the emergence curves show peaks (fig. 3), early for deep samples and progressively later for shallower samples. In November, at the 0 and 10 cm. depths, *C. oryzae* was still increasing but the January samples (fig. 5) show that it ceased egg laying very soon after the taking of November samples. The adverse conditions of temperature and carbon dioxide, even near the surface, coupled with the unusually high air temperature, caused the migration of *C. oryzae* from the grain in December. The metabolism of the larvae must have been slowed down and some of the insects must have died. Reduction of this species to one-quarter of its earlier numbers lessened heat production considerably and enabled the cold air to cool the grain to its own temperature. Cooling affected the sides of the bin first and the free living insects probably moved to the middle of the bin (Table IV). The larger proportion of larvae of *C. oryzae* and *Rhizopertha* at Z must be explained by the later cooling of that region, as both species are vulnerable to low temperatures. Nevertheless, a large number of insects survived until 8th January,

when the temperature was below 5°C., though after three months, very few living insects remained. A small number of *Laemophloeus* probably survived the winter but it is unlikely that any other species did. Robinson (1928, p. 410) suggests that 35°F. would be fatal for *C. granaria* in one month, and the grain was as cold as this for nearly two months. *C. oryzae* and *Rhizopertha* are certainly even more susceptible to cold. The finding of one *C. granaria* and one *C. oryzae* adult and the breeding of two *Lariophagus*, however, make it possible that these species may have survived.

Reduction of the insect population removed the source of carbon dioxide, the concentration of which fell rapidly, only to rise again before the temperature became high enough for insect activity. Since the steep temperature gradients in the grain resulted in an increase of the water content of the grain at the surface and sides of the bin, this grain and more especially the micro-organisms attacking it, probably produced the carbon dioxide recorded in March. In the following July the grain against the bin faces was found to be rotting. Insect activities helped to increase the concentration to a maximum in August 1942.

(c) *The 1942 Infestation.*

The insects attacking the grain in 1942 were mostly *C. granaria*, *Laemophloeus* and *Lariophagus*. The *Laemophloeus* had probably survived in the bin but most of the *C. granaria* came from the neighbouring infested bins, since in 1941 only a very small population of this species was present in this grain. Also Dendy & Elkington (1920b) and Robinson (1926) suggest that *C. granaria* overwinters only as the adult. Adults were observed in some numbers on the surface of the neighbouring bins during the winter but very few were found in this bin. *Lariophagus* did not appear in samples until July, so that unless this species was able to overwinter in diapause, it must have invaded the grain in June or early July. The first adults of the new generation of *C. granaria* probably appeared at about this time and the species increased quite rapidly until the parasitism of *Lariophagus* checked it. In July three times as many parasites as *C. granaria* were bred out. As in the previous year, a high concentration of carbon dioxide accumulated deep in the bin. This prevented the penetration of insects much below 50 cm., at which depth *Laemophloeus* was the most abundant. *Calandra* and *Lariophagus* were most numerous near the surface.

Discussion.

(a) *Temperature.*

The infestation of the grain in 1942, though very much lighter than that of 1941, was quite heavy—the nine 25 cm. samples taken on 27th May, 1942, contained an average of one weevil larva in 200 grains (=approximately 6 g.). It did not, however, cause heating of more than 3°C. above the air temperature and the grain cooled with the air in September. This was due to the restriction of the infestation to the surface layers by the carbon dioxide below, so that the heat produced escaped readily.

The value of temperature as an indicator of grain condition is well known. Kelly (1941) has published an excellent account of temperature changes in grain bins of different sizes, and Attia (1939) has given a detailed account of the changes of temperature in a heap of grain in the open in Egypt. Although Attia was concerned with physical factors and not with insect infestation, it seems unlikely that his piles could be kept free of insects, and some of his results show evidence of heating.

Flanders (1933) has suggested the use of temperature as an indication of the amount of infestation by *Sitotroga cerealella*, Ol., in laboratory cultures. In a warehouse it is more useful to use the amount of infestation as a guide to the likelihood of future heating, so that the deterioration caused by heating can be avoided. The observations made in the present paper indicate that insect infestation deep in the grain is more likely to cause heating than a surface infestation. The present observations

emphasise the importance of weevil larvae compared with the lesser importance of adults (*cf.* Takahashi 1934). Thus it would be wise to examine all bulks soon after they are placed in position, since some of the insects present would be buried deep in the grain. Although many of the free-living forms are killed or injured by the handling of the grain (Rodionov, 1938), many adults do survive it and the larvae of weevils are protected from this rough treatment by the grain in which they live. It is likely that the burying of insects or of other causes of heating is the reason that Kz. (1940) recommends, from many years of experience, that the depth to which stored grain is piled should be limited to one metre. If grain does heat and has to be turned, this process would have to be repeated frequently, for turning will not kill all the insects: otherwise it is advisable to use the grain as quickly as possible. Gay (1941a, b) states that in New South Wales grain in silos is frequently turned. He shows that the value of turning is more in breaking up pockets of infestation than in total cooling. Breaking up such pockets prevents the general tainting caused by small quantities of mouldy grain in a bulk, but it spreads the infestation in the bulk.

When a clean bulk becomes infested, naturally the surface and limiting layers are infested first. If the infestation is unable to penetrate into the bulk the damage done can never affect the whole mass of grain and heating cannot result. Rodionov (1938) suggests that weevils do not penetrate deeper than one metre into grain, and little or no data from warehouse investigations as yet contradicts this idea, but Rodionov's experiments do not prove it. Waloff (unpublished), has found larvae of *Ephestia elutella*, Hb., at one metre, and damage caused by this species at over two metres deep in a bulk stored for some months. *Laemophloeus minutus* has been found down to four metres deep and is suspected of causing heating.

It is recommended that samples of grain should be taken periodically from all bulks in store and tested for the presence of insects either by breeding out or by the method of Howe & Oxley (in preparation). Although climatic conditions in Britain are not very favourable to insects and many species do not survive the winter in unheated premises, nevertheless, insect pests can do a great deal of damage in the warmer months and do survive cold weather in heating piles. Had the bin of grain under investigation been surrounded by a bulk of grain, it would certainly have remained warm enough through the winter for the survival of stored grain pests. Therefore frequent inspection of stocks of grain is necessary.

(b) *Composition of Intergranular Air.*

Previous attention directed toward the oxygen and carbon dioxide content of the intergranular air has had as its object the investigation of airtight storage and its effect on the pests present (Dendy & Elkington, 1920a, Davidson, 1940). This method of limiting the damage of pests is valuable where airtight storage is easily practicable and the probability of infestation is high. In Britain, little of the existing storage available could easily be made airtight except possibly silo bins.

The concentration of carbon dioxide in the intergranular air of bulks of grain depends mainly on the type of store used and so by itself is not of great use in detecting infestation.

(c) *Water Content.*

The need for constant checking of grain water content has been emphasised in many papers. The data obtained from the present investigations shows that subsurface (say 10-20 cm. deep) water content data should be obtained instead of surface data which vary with atmospheric humidity. A deep sample should also be taken since the safety of storage depends largely on the mass of grain being drier than 14-15 per cent. Kelly (1940, p. 7) has shown that the effect of the outside relative humidity is confined to the outer layers of the bulk.

The assertions that metabolic water produced by insects plays a big part in increasing directly the water content of a mass of grain (*e.g.* Davidson, 1940, p. 348) are not upheld by rough calculation, which shows that if no water or heat were to escape, the amount of metabolism required to increase the water content by 1 per cent. would raise the temperature more than 100°C.* Evidently, unless heat can escape freely, it is not possible for an insect population to be sufficiently dense to raise the water content appreciably by the production of metabolic water alone. Ratcliffe *et al.* (1940, p. 235) do not give the details of experiments in which weevils raised the water content of grain by 5 per cent., but it is possible that they were done on a small scale with a very dense population allowing the escape of heat but not of water. Alternatively, the increases in water contents may have been due to translocation of water under the influence of steep temperature gradients. In the bin the dense population probably helped to raise the water content in the latter part of 1941 because, by this time, it was superficial enough for free loss of heat. When the major infestation was deeper and caused heating, the temperature gradient probably caused translocation of moisture from hotter to cooler regions.

The high water content of the surface layers observed in February 1942 thus results from three causes:—

1. Translocation of water from deeper layers as a result of the temperature gradient (May–Sept. 1941).
2. Metabolic water from the dense superficial infestation (Oct.–Dec. 1941).
3. Absorption of water from the atmosphere during the humid winter months (Dec. 1941–Feb. 1942).

Conclusions.

1. Insects, mostly *C. oryzae*, dispersed through a bin of wheat, caused the grain to heat in five months, whilst developing an enormous population in the grain.

2. The high concentration of carbon dioxide produced by the insects made the conditions at the bottom of the bin unsuitable for the insects.

3. The temperature produced became too high for *C. oryzae*, and as a result of the reduction of the numbers of this species and the cold weather, the grain cooled.

4. The maintenance of a steep temperature gradient between the infested grain and the air-cooled surface and sides of the bulk, particularly marked during November and December, resulted in an increase of grain water content at the surface and sides.

5. *C. oryzae* and *Rhizopertha* were killed off by the 1941–42 winter but *Laemophloeus* spp. survived to infest the bin in 1942.

6. Reinfestation, affecting the grain to a depth of 50 cm. only, did not cause heating.

7. In bulks of stored grain, samples from the depths of the grain should be tested for insect life, since infestation in the depths of a bulk will cause heating.

Summary.

One and a half tons of Plate wheat, of water content 12.9 per cent., infested by insects, especially the small form of *C. oryzae*, *Rhizopertha*, and *Laemophloeus*, were

*From the formula $C_6H_{12}O_6 + 6O_2 \rightarrow CO_2 + 6H_2O + 677 \text{ Kgs. Cals.}$, 1 g. of water is produced with about 6 Kgs. Cals. 1 g. of water raises w/c of 100 g. grain by nearly 1 per cent. 6 Kgs. Cals. raise temperature of 100 g. grain

(Sp. Ht. 0.45) by $\frac{6}{0.45} \times \frac{1000}{100} = 133^\circ\text{C.}$

placed in an iron bin in May 1941. By the following November the wheat was heating near the surface and was extremely heavily infested in the 25 cm. surface layer. The carbon dioxide concentration beneath this layer exceeded 10 per cent.

During December the hottest depth in the grain was nearer to the surface. The temperature reached 37°C., 27°C. above air temperature. Many weevils came to the surface in early December and walked off the grain. Then in mid December the grain temperature fell rapidly and reached air temperature by the end of the month. A week later many insects were still alive, but by March 1942 very few living insects were found. The carbon dioxide concentration fell rapidly but rose again in March, presumably due to the increased grain water content and the respiration of micro-organisms.

In 1942, conditions became suitable for insect activities in April, and by May an infestation had started, this time predominantly *C. granaria*. *Laemophloeus* was also present, having apparently survived the winter in the bin, but neither *C. oryzae* nor *Rhizopertha* had survived. Insects were confined to the surface layers by the carbon dioxide present deeper in the bin. Consequently heating did not occur in 1942, and when the grain was moved in October 1942, its temperature was falling after reaching a maximum of 27°C. in August.

The effect of the presence of insects upon grain is discussed. It is shown that the conditions arising in the bin resemble those in general storage, except that the use of an open topped bin with airtight sides and bottom caused a much greater accumulation of carbon dioxide than is usual.

It is suggested that if the grains infested by weevils are buried in the bulk, heating is likely to occur, whilst if the infestation is superficial the grain may not heat. The part played by weevil larvae in the heating of grain is stressed.

It is suggested that regular examination of samples of grain from deep in a bulk should be made for insects and that all bulks should be examined soon after being placed in position. Routine temperature and water content readings should be made at points deep in the grain and about 10-20 cm. below the surface.

Acknowledgments.

This work was done as a part of the normal programme of the Pest Infestation Laboratory. Thanks are due to Mr. F. G. Stickland and Mr. W. A. Carter who did much of the laborious work of examining grain samples.

This paper is published with the consent of the Department of Scientific and Industrial Research.

References.

- ATTIA, R. (1939). The different factors affecting the temperature of a heap of grain in the open.—Bull. Minist. Agric. Egypt, no. 192, 50 pp.
- CHERNUISHEV, P. K. (1939). [About the rate of contamination of grain by pests.] (In Russian.)—Bull. Plant Prot., Leningrad, no. 1 (20), pp. 46-48.
- DAVIDSON, J. (1940). Wheat storage problems in South Australia. [J. Dep. Agric. S. Aust., **44**, pp. 123-136, 243-247, 346-352, 391-395.
- DENDY, A. & ELKINGTON, H. D. (1920a). Report on the effect of airtight storage upon grain insects. Part III.—Rep. Grain Pests Comm. roy. Soc., no. 6, 51 pp.
- & — (1920b). Report on the vitality and rate of multiplication of certain grain insects under various conditions of temperature and moisture.—Rep. Grain Pests Comm. roy. Soc., no. 7, 52 pp.

- FLANDERS, S. E. (1933). Heat production and limitation of densities in *Sitotroga* populations.—Ann. ent. Soc. Amer., **26**, pp. 529-535.
- GAY, F. J. (1941a). Temperature changes during the 'turning' of bulk wheat.—J. Coun. sci. industr. Res. Aust., **14**, pp. 111-116.
- . (1941b). A further study of temperature changes during the 'turning' of bulk wheat.—J. Coun. sci. industr. Res. Aust., **14**, pp. 245-248.
- & RATCLIFFE, F. N. (1941). The importance of *Rhizopertha dominica* as a pest of wheat under wartime storage conditions.—J. Coun. sci. industr. Res. Aust., **14**, pp. 173-180.
- HOWE, R. W. & OXLEY, T. A. The use of carbon dioxide output as a measure of the infestation of grain by insects. (In preparation.)
- KELLY, C. F. (1940). Methods of ventilating wheat in farm storages.—Circ. U. S. Dep. Agric., no. 544, 73 pp.
- . (1941). Temperatures of wheat in experimental farm storages.—Circ. U. S. Dep. Agric., no. 587, 60 pp.
- KIESEL, A., VASSILIEVA, N. & TSYGANKOVA, G. (1939). Translocation of moisture in the bulk of stored grain.—C. R. Acad. Sci. U.R.S.S., **24**, pp. 786-790.
- KZ. (1940). Lagerschütthöhen von Getreide.—Mühle, **77**, cols. 43-44.
- OXLEY, T. A. & HENDERSON, F. Y. Properties of grain in bulk I. Instruments for making measurements in grain stored in bulk. (In preparation.)
- RATCLIFFE, F. N., GAY, F. J. & FITZGERALD, J. S. (1940). Wheat weevils and their control.—J. Coun. sci. industr. Res. Aust., **13**, pp. 229-239.
- RICHARDS, O. W. (1943). The two strains of the rice weevil, *Calandra oryzae* (L.) (Coleopt. Curculionidae). (In press.)
- ROBINSON, W. (1926). Low temperature and moisture as factors in the ecology of the rice weevil *Sitophilus oryzae* L. and the granary weevil *Sitophilus granarius* L.—Tech. Bull. Minn. agric. Exp. Sta., no. 41, 43 pp.
- . (1928). Response and adaptation to external stimuli.—Ann. ent. Soc. Amer., **21**, pp. 407-417.
- RODIONOV, Z. (1938). [The regularity of movement of *Calandra granaria* L. in grain heaps.] [In Russian.]—Zool. Zh., **17**, pp. 610-616.
- TAKAHASHI, S. (1934). [Experimental studies on the causes of heat in stored grains, produced by insect pests.] [In Japanese.]—Tokyo, the author, 210 pp. Abstr. in Rev. appl. Ent., (A) **23**, (1935), p. 676.
-

RESISTANCE OF *THEOBROMA CACAO* TO *SAHLBERGELLA* SPP. ON THE GOLD COAST.

By A. F. POSNETTE, B.A., A.I.C.T.A.

The damage done to cacao (*Theobroma*) in West Africa by certain species of CAPSIDAE has been described by Dudgeon (1910), Cotterell (1926) and Voelcker and West (1940). At the start of a selection programme aimed at developing strains of cacao resistant or tolerant to such damage, it was considered necessary to develop a laboratory technique for testing the palatability of selections. It is noticeable in the field that certain trees appear consistently to escape attack; this might be due to some form of unattractiveness to the Capsids. One of the most obvious forms of preference which seems to be shown by these bugs is that of *Sahlbergella theobroma* for seedlings and young trees up to about six years old and that of *S. singularis* for mature trees. Indeed until very recently there was no field record of *S. singularis* attacking seedlings in the Gold Coast.* Conversely, attacks by *S. theobroma* on mature trees are confined almost entirely to pods, while the other species causes severe damage to shoots. Dudgeon (*loc. cit.*) reports old trees "exhibiting damaged bark and dead branches" in the presence of *S. theobroma*, but these may have been feeding on pods.

RESULTS OF EXPERIMENT.

<i>Sahlbergella theobroma</i>								<i>Sahlbergella singularis</i>							
Nymphs	Adults	No. of punctures						Nymphs	Adults	No. of punctures					
		Young tree			Old tree					Young tree			Old tree		
		(a)	(b)	Total	(a)	(b)	Total			(a)	(b)	Total	(a)	(b)	Total
4		6	3	9	20	10	30								
3	1	31	35	66	22	—	22								
5	1	39	49	88	40	22	62	2	2	10	4	14	6	41	47
4	2	46	60	106	7	7	14	3	1	3	2	5	15	7	22
4	2	25	41	66	20	27	47	3	1	2		2	2	18	20
3	1	66	30	96	3	5	8	1	1	3	8	11	5	1	6
3	1	12	9	21	30	64	94	1	1	2	1	3	8	19	27
3	1	3	35	38	38	17	55	2	1	42	34	76	10	5	15
3	2	—	2	2	82	48	130	2	1	6	15	21	41	38	79
5		48	62	110	13	3	16	2		1	25	26		7	7

* Three nearly mature nymphs of *S. singularis* were taken by the writer on 18 month old cacao seedlings at Adonkwanta, near Ibadan, on 23rd February, 1943. Also, on 20th December 1942, nymphs and adults of *S. singularis* were found on *Theobroma bicolor* seedlings at Ibadan.

The experiment, of which the results are given above, was designed to show whether this unexplained choice is due to the unpalatability of the sap in each case. The variety of cacao known as " West African Amelonado " was used throughout.

Unattacked shoots of the same age and in the same stage of flush were chosen from young and old trees where they were being attacked by their specific pest. On 1st May, 1940, two shoots of each type of tree were placed in water in a cage with nymphs and adults of *S. theobroma*. Two days later an identical cage was arranged using *S. singularis*, and thereafter the two species were run concurrently. The shoots in each cage were so arranged that their foliage mingled, and bugs could walk easily from one to the other.

After 24 hours, the shoots were removed and the feeding punctures counted on each shoot. The procedure was then repeated with fresh plant material and insects until sufficient data had accumulated for statistical analysis.

STATISTICAL ANALYSIS.

Types examined separately :—

<i>S. theobroma</i>				Degrees F.	Sum squares	Mean sq.
Between trees	...	...	...	1	384.4	384.4 not sig.
Between exps.	...	...	...	9	2,071.0	230.1
Trees $\times$ exps.	...	...	...	9	12,230.6	1,357.9 sig.
Residual	...	...	...	20	3,460.0	173.0
				39	18,146.0	465.3
<i>S. singularis</i>						
Between trees	...	...	...	1	132.0	132.0 not sig.
Between exps.	...	...	...	7	1,836.9	262.4
Trees $\times$ exps.	...	...	...	7	2,305.3	329.3 sig.
Residual	...	...	...	16	1,276.5	79.8
				31	5,550.7	179.1

The difference between puncturing of old and young tree is not significant in either species.

The significance of interaction $T \times E$ in both types suggests indifference by both species.

Insects appear to feed on first shoot they reach irrespective of age of tree.

When both types examined together :—

	Degrees F.	Sum squares	Mean sq.
Between species	1	5,112.2	5,112.2 <i>sig.</i>
Between trees	1	20.2	20.2 not <i>sig.</i>
Between exps.	7	1,317.2	188.2
S × T	1	430.2	430.2 not <i>sig.</i>
T × E	7	9,109.0	1,301.3
S × E	7	1,053.0	150.4
T × B × S	7	4,628.2	661.2 <i>sig.</i>
Residual	32	4,432.0	138.5
	63	26,102.0	414.3

Difference between puncturing of old and young tree is not significant.

Difference between double interaction $T \times B \times S$ is significant relative to error.

No other differences are significant relative to interaction.

$S \times T$, which measures attack of one species on old tree and other species on young tree, is *not* significant.

Conclusions.

Neither *Sahlbergella theobroma* nor *S. singularis* exercises any constant choice: they feed on shoots of old and young trees indiscriminately, but show some tendency to concentrate on one shoot; this may be a sign of gregarious habit, as no other reason for the choice seems apparent.

Discussion.

The results of this experiment indicate little promise of discovering unpalatable trees, but trials were made, using the same technique, with selected trees which had escaped attack in heavily infested farms. Each cage contained shoots from "immune" and susceptible trees; the bugs showed no consistent discrimination against the "immune" trees.

Attention was therefore turned to selection for tolerance, and a clone has now been developed which does withstand attack without serious damage. In the field this selection is very rarely attacked, but as bugs feed normally when it is infested by hand, the reason for this is as obscure as that for the choice of seedlings by *S. theobroma* and of mature trees by *S. singularis*.

Acknowledgments.

I am indebted to Mr. H. E. Box, F.R.E.S., Cocoa Research Entomologist, for his helpful suggestions concerning the preparation of this paper; and to Mr. H. B. Waters, Director of Agriculture, for permission to publish.

References.

- COTTIERELL, G. S. (1926). Preliminary study of the life-history and habits of *Sahlbergella singularis*, Hagl., and *S. theobroma*, Dist.—Bull. Dep. Agric. Gold Coast, no. 3.
- DUDGEON, G. C. (1910). Notes on two West African Hemiptera injurious to cocoa.—Bull. ent. Res., **1**, p. 59.
- VOELCKER, O. J. & WEST, J. (1940). Cacao dieback.—Trop. Agriculture, **17**, p. 27.
-

THE LARVAE OF THE LEPIDOPTERA ASSOCIATED WITH STORED PRODUCTS.

By H. E. HINTON, Ph.D.

Department of Entomology, British Museum (Nat. Hist.).

Introduction	...	...	...	...	...	...	...	...	...	163
Method and Explanation of Terms	...	...	...	...	...	...	...	...	...	163
Key to Families and Species	...	...	...	...	...	...	...	...	...	165
Nolidae	...	...	...	...	...	...	...	...	...	172
Geometridae	...	...	...	...	...	...	...	...	...	173
Agrotidae	...	...	...	...	...	...	...	...	...	174
Pyalidae	...	...	...	...	...	...	...	...	...	175
Tortricidae	...	...	...	...	...	...	...	...	...	203
Gelechiidae	...	...	...	...	...	...	...	...	...	204
Cosmopterygidae	...	...	...	...	...	...	...	...	...	204
Oecophoridae	...	...	...	...	...	...	...	...	...	205
Tineidae	...	...	...	...	...	...	...	...	...	210
Acknowledgements	...	...	...	...	...	...	...	...	...	212
References	...	...	...	...	...	...	...	...	...	212

Introduction.

During the last year, while I was engaged in work on stored product pests for the Infestation Branch of the Ministry of Food, the necessity arose for identifying Lepidopterous larvae damaging stored food. It was soon found that with few exceptions the available descriptions of these larvae are quite inadequate, as they are usually based entirely on colour, and it became necessary to employ more precise methods. The arrangement of the setae (chaetotaxy) together with other structural characters proved to be reliable for distinguishing the species. By these means those concerned should be able to identify without undue difficulty most of the moth larvae they are likely to encounter. Altogether 35 out of some 70 species which have been found associated with stored products in all parts of the world, can be positively identified by means of the keys and descriptions given in this paper. These 35 species include all the more important British ones and seven which have not yet been recorded in Britain, viz.: *Celama sorghuella* (Riley), *Cryptoblabes gmidella* (Mill.), *Acrobasis arvic.* Grote, *A. uglandis* (Le Barou), *Etiella zuckenkella* (Freit.), *Pyroderces rileyi* (Wals.), and *Anthonoma xeraula*, Meyr.

The data concerning the distribution have been supplied by Dr. A. Steven Corbet and Mr. W. H. T. Tams and are based on authentic material in the British Museum. The order in which the families and lower systematic categories are arranged in the keys and descriptions is governed only by convenience and not by phylogenetic considerations, e.g., the most primitive family, TINEIDAE, is dealt with last.

Method and Explanation of Terms.

The vast majority of the existing descriptions of the larvae of the Lepidoptera are based solely on colour and size, and, whatever may be the case as regards the Macrolepidoptera, these are of very little value for the purpose of identifying the larvae of

the Microlepidoptera. For example, the standard handbook of the British Lepidoptera by Meyrick (1928) describes the larva of the common clothes moth, *Tineola bisselliella*, as follows: "Larva whitish; head brown." It is clear that such a description will apply equally well to the majority of the Microlepidoptera and many of the Macrolepidoptera. Although this description is short, it is by no means unusually so. Even in the case of the more detailed descriptions of colour, such as those given by Buckler (1901) and Barrett (1904) for the larvae of the PYRALIDAE, the complete absence of any structural characters make them for the most part equally useless. Nor is the situation much better as regards the illustrations given by these and other authors. When the larvae have striking or unusual colour patterns, these illustrations are adequate, but the coloured drawings of the majority of the Microlepidoptera cannot be relied on for the positive identification of the species however much they may appeal to the aesthetic senses.

In order properly to study the structure and chaetotaxy of the larvae, it is necessary to preserve them in Pampel's fluid, alcohol, or any of the other well-known preservatives. Unfortunately, most of the existing collections of larvae in this country contain only blown specimens, and these have usually lost many of their setae, and the relative positions of the remaining setae have been distorted in the process of blowing.

Through the efforts chiefly of Dyar, Forbes, and Fracker and more recently of Heinrich, Gerasimov, and Benander, the classification of Lepidopterous larvae has been placed on a relatively sound footing, although much remains to be done. Keys to the families have been given by Fracker (1915), Forbes (1923), Brues & Melander (1932), and Gerasimov (1937), those of the last named being the most complete.

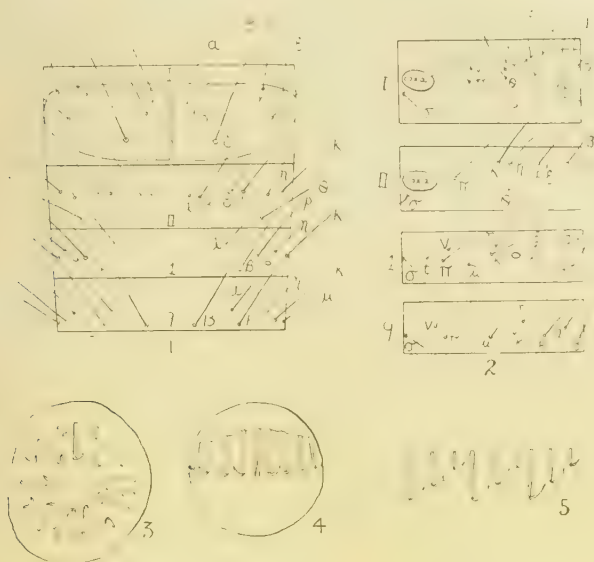
The nomenclature used here for the setae of the thorax and abdomen is that elaborated by Fracker (1915) and illustrated in figs. 1-2. Each seta is indicated by a lower case Greek letter, and the following is a list of the setae used in this paper:

α alpha	η eta	π pi
β beta	θ theta	ρ rho
γ gamma	κ kappa	σ sigma
δ delta	μ mu	ι tau
ε epsilon	ν nu	

Some of these setae are always associated with others in definite groups, and these groups are indicated by capital Greek letters as follows: Beta, B ($\alpha + \beta$); Kappa, K ($\theta + \kappa + \eta$); Rho, P ($\varepsilon + \rho$); and Pi, Π ($\nu + \pi$ on thorax, $\nu + \pi + \iota$ on abdomen). Kappa and eta vary considerable in position in relation to each other, and in order to avoid confusion I have in all cases called the larger seta kappa and the smaller eta. On the prothorax of many families theta is present, and, apart from the fact that it is usually nearer to the spiracle than the other two, it is always smaller than eta. In all Lepidoptera the first-instar larva differs from the second and, although these differences vary in kind and degree with the particular species, the following setae are absent in the first-instar larva of all Frenatae (the suborder which includes the families dealt with here): theta and mu on all segments of thorax and abdomen and eta on meso- and metathorax.

There are three kinds of setae. The primary setae are all those present in the first instar, the subprimary setae are those having a definite position on the body but not present on the first instar of the more primitive groups, and the secondary setae are those which are numerous, have a general distribution, and are characteristic of the hairy caterpillars, e.g. ARCTIIDAE, some AGROTIDAE, etc., but are absent in the PYRALIDAE and all the true Microlepidoptera. Many larvae have a pinnaculum or small, usually oval area which is often highly pigmented and more or less sclerotised at the base of some or all of the setae.

The nomenclature of the head is similar to that given by Forbes (1910), and the few cephalic setae used in this paper are numbered in figs. 36, 38. Forbes' system of nomenclature is adopted only for the purposes of this paper, a better nomenclature and one now generally in use by the few workers who use the setal characters is explained by Heinrich (1916). The ocelli are numbered as shown in fig. 7, and the parts of the head are named as shown in fig. 36. The crochets of the prolegs of the species dealt with in this paper are arranged in a complete circle (fig. 3), a penellipse (fig. 86), or a mesoseries (fig. 4) and may be uniordinal (fig. 4), biordinal (fig. 3), or triordinal (fig. 5). In order to save space in the descriptions of families and species Roman numerals are used to designate the segments of the body behind the head, I, II, III for the thorax and 1, 2, 3, 4, &c., for the abdomen.



Figs. 1-5. (1) Dorsal view of prothorax and mesothorax and first and ninth abdominal segments. (2) Lateral diagrammatic view of same segments. (3) Biordinal crochets arranged in a complete circle. (4) Uniordinal crochets arranged in a mesoseries. (5) Triordinal crochets.

Lines next to figures refer to a length of 0.20 mm. unless otherwise indicated. All illustrations accompanied by an indication of magnification have been drawn with the aid of a camera lucida.

Key to the Larvae of the Moths associated with Stored Products.

1. Prolegs short, narrow, and often very indistinct and each with only two crochets (Thoracic legs small. Body 7 mm. long or less. Always inside grain except in first instar). Cosmopolitan. (GELECHIIDAE, part)...*Sitotroga cerealella*, Oliv.
- Prolegs distinct and well developed and each proleg always with many crochets.....2

2. Thorax and abdomen with numerous wart-like tubercles (fig. 6) which are thickly clothed with pointed spines and long, slender hairs. Abdomen with four pairs of prolegs. N. & S. America. (NOLIDAE).....
Celama sorghiella (C. V. Riley)
 Thorax and abdomen without secondary hairs or spines but sometimes with a few sub-primary setae below level of spiracles. Abdomen with two or five pairs of prolegs.....3
3. Prolegs present only on sixth and tenth abdominal segments. Dorsal and most of ventral setae of thorax and abdomen short and club-shaped. Europe, temperate Asia, N. Africa. (GEOMETRIDAE).....*Sterrrha inquinata* (Scop.)
 Prolegs present on third to sixth and tenth abdominal segments. Dorsal and ventral setae of thorax and abdomen always long and pointed.....4
4. Crochets of four anterior pairs of prolegs arranged in a mesoseries (fig. 4) or penellipse (fig. 86).....5
 Crochets of four anterior pairs of prolegs arranged in a complete or nearly complete circle.....6
5. Crochets of four anterior pairs of prolegs arranged in a uniordinal mesoseries (fig. 4). Europe, temperate Asia. (AGROTIDAE).....*Apamea sordens* (Hufn.)
 Crochets of four anterior pairs of prolegs arranged in a bi- or triordinal penellipse (fig. 86). Nearly cosmopolitan. (PYRALIDAE, part).....
Euchromius ocella (Haw.)
6. Kappa group of prothorax bisetose, theta absent. (PYRALIDAE) 7
 Kappa group of prothorax trisetose, theta present.....23
7. Prothorax (fig. 29) with distance between rho and epsilon much less than distance between gamma and epsilon (Kappa setae of prothorax in a nearly horizontal line). In most tropical and subtropical regions.....*Etiella zinckenella* (Treit.)
 Prothorax (figs. 39, 42) with distance between rho and epsilon at least as great as distance between gamma and epsilon.....8
8. Kappa setae of prothorax in a horizontal or feebly oblique line. First abdominal segment with a sclerotised ring enclosing a membranous area around base of seta rho. Pi group of meso- and metathorax sometimes bisetose. (Gallerinae) 9
 Kappa setae of prothorax in a vertical or nearly vertical line. First abdominal segment without a sclerotised ring enclosing a membranous area around base of seta rho. Pi group of meso- and metathorax always unisetose.....13
9. Pi group of meso- and metathorax bisetose. Head with four ocelli on each side or without distinct ocelli; mandible (figs. 14-15) without a subapical tooth on ventral surface of outer tooth.....10
 Pi group of meso- and metathorax unisetose. Head with six ocelli on each side; mandible (fig. 16) with a sublateral, subapical tooth which does not form part of outer margin but is on ventral surface of outer tooth.....11
10. Head with four ocelli (fig. 13) on each side; mandible (fig. 14) with outer ventral margin not broadly or distinctly sinuate at apical third; setae i and ii about equally distant from the puncture between them (fig. 11). Peritreme of spiracles (fig. 12) moderately pale brown and evenly thickened, the caudal part of each being no thicker than the anterior part. Prothorax with Kappa setae in a line opposite dorsal margin of spiracle or even above spiracle. Abdomen with eta of first eight segments directly anterior or antero-dorsal to kappa so that setae are in a feebly oblique line (fig. 12); seventh segment with nu nearly directly lateral (only slightly anterior) to pi. Prolegs with small crochets usually about two-thirds to four-fifths as long as large ones. Cosmopolitan.....*Galleria mellonella* (L.)

Head without distinct ocelli ; mandible (fig. 15) with outer ventral margin very broadly and distinctly sinuate at apical third ; puncture between setae i and ii much nearer to ii than to i and seta i nearly directly mesal to ii. Peritreme of spiracles black or nearly so and prothoracic and first seven abdominal spiracles with caudal part of peritreme twice or nearly twice as thick as anterior part. Kappa setae of prothorax in a line opposite ventral margin of spiracle. Abdomen with eta of first eight segments directly dorsal to kappa (fig. 18) so that these setae are in a vertical line ; seventh segment with nu nearly directly anterior (only slightly lateral) to pi. Prolegs with small crochets only one-third to one-half as long as large ones. Throughout old world.....*Achroia grisella* (F.)

11. Head (fig. 19) with boundaries of adfrontals joining coronal suture at a point three times as far from front as from vertical triangle. Spiracles with peritreme very thick, the caudal part of peritreme of eighth abdominal spiracle (fig. 22) four times as thick as base of seta rho of same segment. Pi group of abdominal segments three to six (fig. 21) with nu directly anterior or at most only slightly antero-lateral to pi. Kappa group of ninth abdominal segment (fig. 20) with mu usually twice as far from kappa as is eta. Eighth abdominal segment with distance between rho and epsilon slightly less than horizontal diameter of spiracle (Cuticle of abdomen pale yellow.). Cosmopolitan but apparently absent in tropics.....*Aphomia sociella* (L.)

Head (figs. 27, 23) with boundaries of adfrontals joining coronal suture at a point slightly to very much less than three times as far from front as from vertical triangle. Peritreme of eighth abdominal spiracle with caudal part only twice or less than twice as thick as basal part of seta rho of same segment (fig. 26). Pi group of abdominal segments three to six (fig. 25) with nu directly lateral or antero-lateral to pi. Kappa group of ninth segment (fig. 24) with mu no further from kappa than is eta or only very slightly further. Eighth abdominal segment with distance between rho and epsilon slightly greater than horizontal diameter of spiracle.....12

12. Head (fig. 23) with boundaries of adfrontals joining coronal suture at a point about half way or very slightly more than half way between front and vertical triangle. Abdomen with spiracles (fig. 26) with caudal and anterior part of peritreme of each equally thick or with caudal part only slightly thicker than anterior part ; Alpha, Beta, Rho and Kappa setae of segments one to seven nearly always with distinct pinnaculæ (Cuticle of abdomen creamy-yellow or yellowish grey). Nearly cosmopolitan*Aphomia gularis* (Zell.)

Head (fig. 27) with boundaries of adfrontals joining coronal suture at a point about twice as far from front as from vertical triangle. Abdomen with dorsal and lateral setae of first seven segments without or, rather seldom, with only indistinct pinnaculæ ; spiracles (fig. 28) with caudal part of peritreme one and a half to two times as thick as anterior part (Cuticle of abdomen usually white). Cosmopolitan.....*Corcyra cephalonica* (Staint.)

13. Mesothorax with a sclerotised ring enclosing a membranous area around base of seta rho. (Phycitinae).....14

Mesothorax without a sclerotised ring enclosing a membranous area around base of seta rho. (PYRALINAE).....

14. Head (fig. 32) with front extending two-thirds of distance to vertical triangle. Abdomen with setae of first nine segments not arising from pinnaculæ, but rho of eighth with a sclerotised ring around base ; Pi group of three to six with nu distinctly lateral to pi (Cuticle of non-sclerotised parts white. Second

- ocellus often fused to first. Kappa group of first seven abdominal segments in a nearly vertical line. Spiracles distinctly projecting as in the species of *Ephestia*, and dorsal rim of each narrow). Cosmopolitan.....
Plodia interpunctella (Hbn.)
- Head (figs. 46-49) with front extending only half or very slightly more than half of distance to vertical triangle. Abdomen with all dorsal and lateral setae except sometimes epsilon arising from distinct pinnaculæ; Pi group of segments three to six with nu sometimes (*Cryptoblabes*, *Acrobasis*, *Ephestia sericarium*) directly anterior or even slightly mesal to pi and sometimes (*Ephestia*) antero-lateral to pi 15
15. Mandible (fig. 34) with a small, ventral, subapical notch on outer tooth. Prothorax (fig. 33) with beta distinctly nearer to delta than to alpha; pronotal sclerite united with pre-spiracular sclerite. Abdomen with kappa of eighth segment directly dorsal to eta or nearly so (Non-sclerotised parts of cuticle dark brownish with pinnaculæ blackish, each being surrounded by a pale area. First seven abdominal segments with Kappa setae in an oblique line.). Mediterranean Basin.....*Cryptoblabes gnidiella* (Mill.)
- Mandible (figs. 48, 50) without a ventral, subapical notch on outer tooth. Prothorax (figs. 39, 42) with beta slightly or much nearer to alpha than to delta; pronotal sclerite never united to sclerite in front of spiracle. Abdomen with kappa of eighth segment ventral or ventro-caudal to eta, very rarely slightly dorsal to eta.....16
16. Non-sclerotised parts of cuticle dark brownish or greyish brown with pinnaculæ distinctly paler than adjacent parts of cuticle. Ocelli with second slightly nearer to third than to first (fig. 40). Maxillary mala (fig. 43) with both ventral spines apically bifid. Abdomen with Kappa setae of first seven segments in an oblique line; epsilon of one to eight minute and very indistinct or absent. Peritreme of spiracles, particularly of prothorax and eighth abdominal segment, broad, flattened, not strongly projecting, and without a dorsal rim which is distinct from sides. (*Acrobasis*).....17
- Non-sclerotised parts of cuticle white or nearly so that pinnaculæ are distinctly darker than adjacent parts of cuticle. Ocelli with second nearer to first than to third or equally distant between first and third. Maxillary mala (fig. 46) with both ventral spines simple, the apex of each not being forked. Abdomen with Kappa setae of first seven segments in a vertical or nearly vertical line; epsilon of one to eight moderately long and distinct. Peritreme of spiracles strongly projecting, vertical, and with a very narrow dorsal rim sharply distinct from the broad sides. (*Ephestia*).....18
17. Prothorax (fig. 39) with gamma only very slightly nearer to epsilon than to alpha (9:10). Abdomen with alpha of ninth segment nearer to beta than to rho and frequently on the same pinnaculum as beta. Southern United States.....*Acrobasis juglandis* (Le Baron)
- Prothorax (fig. 42) with gamma only half as far from epsilon as from alpha. Abdomen with alpha of ninth segment nearer to rho than to beta on at least one side and sometimes on both right and left sides. United States.....
Acrobasis caryae, Grote
18. Eighth abdominal segment with epsilon (fig. 53) separated from the spiracle by a distance equal to, distinctly less, or very slightly more than the diameter of the spiracle (Mandible with outer tooth, when viewed ventro-mesally, forming part of outer margin of mandible. Prothorax with diameter of spiracle about equal to distance between Kappa setae. Eighth abdominal spiracle about as broad as membranous area enclosed by sclerotised ring around base of seta rho of same segment. Pi group of abdominal segments three to six with nu always distinctly antero-lateral to pi; eighth with nu antero-mesal to pi.). Cosmopolitan.....*Ephestia cautella* (Walker)

- Eighth abdominal segment with epsilon (figs. 52, 54) separated from spiracle by a distance equal to nearly two or even three times the diameter of the spiracle..... 19
19. Mandible (fig. 58), when viewed ventro-mesally, with outer ventral tooth not forming part of outer margin of mandible, this margin being part of largest tooth. Prothorax (fig. 56) with diameter of spiracular opening as great or slightly greater than distance between Kappa setae. Eighth abdominal segment with spiracle (fig. 52) as broad or broader than membranous area enclosed by sclerotised ring around base of seta rho. Pi group of abdominal segments three to six with nu antero-lateral to pi except in fully grown larvae where nu is either directly anterior or even antero-mesal to pi; eighth segment with nu directly anterior or antero-lateral to pi, only in early instars being occasionally very slightly mesal to pi. Cosmopolitan.....*Ephestia sericarium* (Scott)
- Mandible (fig. 57), when viewed ventro-mesally, with outer tooth forming part of outer margin of mandible. Prothorax (fig. 55) with diameter of spiracular opening distinctly less than distance between Kappa setae. Eighth abdominal segment with spiracle (fig. 54) not more than two-thirds as broad as membranous area enclosed by sclerotised ring around base of seta rho. Pi group of abdominal segments three to six with nu antero-lateral to pi; eighth segment with nu slightly mesal to pi. Cosmopolitan.....*Ephestia elutella* (Hbn.)
20. Pi group of ninth abdominal segment unisetose.....21
- Pi group of ninth abdominal segment bisetose.....22
21. Head (fig. 63) with boundaries of adfrontals joining coronal suture at a point about half way or slightly less than half way between front and vertical triangle; with only four distinct ocelli on each side (fig. 65), the first two being fused and the fifth absent or scarcely noticeable; seta vii (fig. 65) antero-dorsal to second (really third) ocellus; mandible (fig. 66) with two large apical teeth and without a distinct ventral, subapical tooth. Abdomen with dorsal and ventral setae of first seven segments without distinct pinnaculæ; Pi group of tenth segment arranged as shown in fig. 64 (Cuticle of thorax and abdomen whitish or greyish with second to seventh abdominal segments usually distinctly paler than others.). Cosmopolitan.....*Pyrallis farinalis* (L.)
- Head (fig. 67) with boundaries of adfrontals joining coronal suture at a point about three times as far from vertical triangle as from front; with six distinct ocelli on each side (fig. 69); seta vii (fig. 69) caudal to third and ventral to second ocellus; mandible (fig. 68) with two large apical teeth and with a third large but appressed, subapical, ventral tooth. Abdomen with all or nearly all dorsal and ventral setae situated on distinct pinnaculæ; Pi group of tenth segment arranged as shown in fig. 70 (Cuticle of thorax and abdomen pale brown to dark olivaceous mottled with large, very dark brown or black patches). Cosmopolitan.....*Hypsopygia costalis* (F.)
22. Head with seta vii (fig. 75) between second and third ocelli but slightly nearer to third than to second; mandible (fig. 76) with outer ventral margin broadly and deeply sinuate before base and without a small ventral tooth before apex of large tooth. Abdomen with mu of ninth segment directly ventral to kappa and nearly twice as far from kappa as is eta from kappa (fig. 74), mu not being situated on the same pinnaculum as eta and kappa; alpha directly anterior to rho (Cuticle of thorax, except pronotal sclerite, dark slate-grey and abdomen paler slate-grey. Sometimes olive-brown mottled with darker patches). Europe, temperate Asia, Africa.....*Aglossa pinguinalis* (L.)

- Head with seta vii directly dorsal to third ocellus (fig. 77) ; mandible (fig. 79) with outer ventral margin evenly rounded before base and with a short, inconspicuous ventral tooth before apex of large tooth. Abdomen with mu of ninth segment caudo-ventral to kappa and slightly nearer to kappa than is eta (fig. 78), all three setae of Kappa group being situated on the same pinnaculum ; alpha slightly but distinctly mesal to rho (Cuticle of thorax and abdomen densely mottled with moderately dark brown to very dark brown patches). Cosmopolitan..... *Aglossa caprealis* (Hbn.)
23. Kappa and eta of abdomen close together and often on same pinnaculum.....24
Kappa and eta of abdomen very widely separated. (TINEIDAE).....29
24. Pi of eighth abdominal segment bisetose and rho directly anterior to spiracle (fig. 91). Beta setae of ninth abdominal segment very close together and usually on same pinnaculum. (TORTRICIDAE).....25
Pi of eighth abdominal segment unisetose and rho usually dorsal (OECOPHORIDAE) but sometimes (*Pyroderces*) anterior to spiracle.....26
25. Ninth abdominal segment (fig. 91) with alpha on same pinnaculum as rho and closer to rho than to beta ; mu usually (80 per cent. of specimens) not on same pinnaculum as eta and kappa (fig. 91). Nearly cosmopolitan.....
Enarmonia pomonella (L.)
Ninth abdominal segment with alpha on a separate pinnaculum and as close to beta as to rho ; mu on same pinnaculum as kappa and eta. Europe, Asia Minor, United States.....*Enarmonia nigricana* (F.)
26. Head with adfrontals extending to vertical triangle. Kappa and eta of prothorax (fig. 92) in a vertical line. Rho of eighth abdominal segment (fig. 93) directly anterior to spiracle. Queensland, southern United States, Jamaica, Hawaii (COSMOPTERYGIDAE, part).....*Pyroderces rileyi* (Wals.)
Head with adfrontals (figs. 113, 115) ending well before vertical triangle except in *Hofmannophila*. Kappa and eta of prothorax (fig. 96) in a feebly oblique or nearly horizontal line. Rho of eighth abdominal segment (fig. 97) directly dorsal to spiracle or nearly so. (OECOPHORIDAE).....27
27. Head (fig. 99) with six ocelli on each side. Mandible (fig. 101) with only one well developed apical tooth. Crochets triordinal. India to Japan.....
Anchonomia xeraula, Meyr.
Head (figs. 107, 112) with less than six ocelli on each side. Mandible (fig. 111) with three well developed apical teeth. Crochets biordinal.....28
28. Head with adfrontals (fig. 114) extending in a very narrow line in coronal suture to, or nearly to, vertical triangle ; frontal puncture (fig. 110) only very slightly closer to frontal than to caudal clypeal seta ; each side with four ocelli (fig. 107) ; labium without a basal pit enclosed by a sclerotised line. Abdomen with Pi group of 1 bisetose ; Pi group of 3-6 (fig. 108) with nu lateral to pi ; spiracle of eight sometimes round but usually with vertical diameter distinctly greater than horizontal, being sometimes nearly twice as great. Trochanter of front leg without a gibbosity on inner or ventral side. Cosmopolitan.....
Hofmannophila pseudospretella (Staint.)
Head with adfrontals (fig. 113) ending abruptly some distance from vertical triangle ; frontal puncture (fig. 115) twice as far from caudal clypeal as from frontal seta ; each side with two ocelli (fig. 112) ; labium (fig. 116) with a large, round, basal depression* defined by a thin line of heavily sclerotised

* In a few specimens this area is flat, in a few it is convex, but in all it is enclosed by a narrow sclerotised line.

- cuticle. Abdomen with Pi group of 1 trisetose; Pi group of 3-6 (fig. 109) with nu directly anterior to pi; spiracle of eight always round or very broadly oval. Trochanter of front leg with a large, prominent gibbosity on inner or ventral side. Cosmopolitan.....*Endrosis sarcitrella* (L.)
29. Pi group of meso- and metathorax unisetose.....30
 Pi group of meso- and metathorax bisetose.....32
30. Head with six ocelli on each side (fig. 119); front extending two-thirds of distance to vertical triangle. Prothorax (fig. 118) with rho nearly in a line with gamma and epsilon and much nearer to both of these than gamma is to epsilon. Pi group of first abdominal segment bisetose; Pi of third to sixth abdominal segments with nu as near or slightly nearer to pi than is tau. Kappa and eta of first eight abdominal segments in an oblique line with kappa dorsal to eta and directly caudal to spiracle. Spiracles of seventh abdominal segment about three-fourths as large as those of eighth (Epsilon of first eight abdominal segments absent. Pi group of ninth abdominal segment bisetose. Fully grown larva 9-11 mm. long.). Europe, Japan.....*Tinea granella* (L.)
- Head with two ocelli on each side or without distinct ocelli; front extending less than one-half of distance to vertical triangle. Prothorax (fig. 121) with rho considerably behind gamma and epsilon and nearly as far or further from these than gamma is to epsilon. Pi group of first abdominal segment trisetose; Pi of third to sixth abdominal segments with nu half again to three times as far from pi as is tau. Kappa and eta of first eight abdominal segments in a horizontal or nearly horizontal line, kappa being considerably below spiracle. Spiracles of seventh abdominal segment only about half as large as those of eighth 31
31. Head without distinct ocelli (without convex lenses, but sometimes with a few pigment spots below a large pale area of cuticle which is in usual position of fourth ocellus). Mandible (fig. 122) with a single large tooth. Prothorax (fig. 120) with kappa ventral and distinctly anterior to theta. Epsilon of first eight abdominal segments absent. Pi of ninth abdominal segment unisetose. Spiracles with peritreme black or nearly so. Fully grown larva 24-28 mm. long. Nearly cosmopolitan.....*Lindera tessellatella*, Blanch.
- Head with two distinct ocelli on each side, each ocellus having a distinctly convex lens. Mandible (fig. 123) with three apical teeth and a smaller sub-apical tooth on ventral side of large outer tooth. Prothorax (fig. 124) with kappa directly ventral to theta. Epsilon of first eight abdominal segments present. Pi of ninth abdominal segment bisetose. Spiracles with peritreme moderately pale brown. Fully grown larva 12-14 mm. long. Britain.....*Tinea ditella* (Pierce & Metcalfe).
32. Head without ocelli. Pi setae of meso- and metathorax in a feebly oblique or nearly horizontal line. Pi group of ninth abdominal segment absent. Epsilon of first eight abdominal segments dorsal and considerably anterior to spiracle. Spiracles of seventh abdominal segment approximately as large as those of eighth. Cosmopolitan.....*Tineola bisselliella* (Hummel)
- Head with one distinct ocellus on each side. Pi setae of meso- and metathorax in a vertical or nearly vertical line. Pi group of ninth abdominal segment unisetose (except possibly in *Tinea pellionella*). Epsilon of first eight abdominal segments more or less directly dorsal to spiracle. Spiracles of seventh abdominal segment only one-half to two-thirds as large as those of eighth 33
33. Kappa and eta of first eight abdominal segments in a nearly vertical line with kappa dorsal to eta and nearly directly caudal to spiracle. Cosmopolitan.....*Trichophaga tapetzella* (L.)

- Kappa and eta of first eight abdominal segments in a horizontal or nearly horizontal line with kappa considerably below spiracle.....34
34. Prothorax (fig. 125) with distance between rho and epsilon about equal to that between epsilon and gamma ; kappa (fig. 126) between and below theta and eta so that it is ventro-caudad to eta. Pi setae of first nine abdominal segments long and distinct. Without a case. Europe.....*Tinea pallescentella*, Staint.
- Prothorax (fig. 127) with distance between rho and epsilon twice as great as that between epsilon and gamma ; kappa (fig. 128) directly ventral to eta. Pi setae of first nine abdominal segments minute and scarcely visible. Always in a fusiform case which is dorso-ventrally flattened. Europe, N. Africa.....*Tinea pellionella* (L.)

NOLIDAE.

Only a single species of this family is dealt with here, *Celama sorghiella* (Riley). No specimens of this species are available, but from the descriptions given by Riley (1882) and Reinhard (1937), together with the characters of the family given by Fracker (1915), no difficulty was encountered in placing it in the key. The following summary of the characters of the NOLIDAE is compiled from Fracker (1915) :

Head smaller than prothorax, partially retractile, smooth and without secondary setae. Each side with six ocelli, the sixth being distant from the upper five, which are in a semicircle enclosing seta vii. Front extending less than half way to vertical triangle. Thoracic legs well developed. Prolegs well developed and present on segments 4-6 and 10 ; crochets in a mesoseries. Chaetotaxy as follows : I with four dorsal verrucae united ; II with four verrucae on each side in a transverse row ; 1-9 with verrucae of Beta, Rho, and Kappa present ; 1-8 with a single verruca between rho and mu, this being Kappa (kappa plus eta ?), which is ventro-caudad to spiracle ; 1-3 and 7 have mu and pi in the form of small verrucae, and sigma is a single seta ; 4-6 with mu discrete but setae of Pi group scattered over proleg and united with sigma ; 8-9 with mu absent but Pi present.

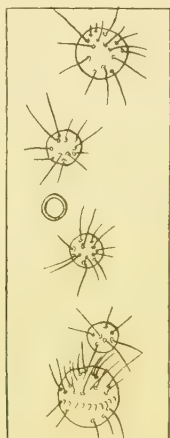


Fig. 6. *Nola cristatula*.—Diagrammatic view of fifth abdominal segment to show chaetotaxy of the Nolidae (after Fracker).

The family NOLIDAE is considered by some writers to be only a subfamily of the ARCTIIDAE. The larvae may be distinguished at once from all Arctiids by having only four instead of five pairs of abdominal prolegs, those of the third abdominal segment being absent.

Celama sorghiella (Riley).

Mature Larva.—Length, 9–14 mm.; breadth, 3–4 mm. Cuticle yellowish or pale greenish-yellow with two moderately broad, brownish, dorsal stripes and sometimes narrow subdorsal and lateral lines of the same colour; dorsal line almost sulphur-yellow; head yellow; legs yellowish and brownish. Verrucae with short, stout, very sharp spines which are yellow with brownish tips, those of lateral verrucae being intermixed with a few long and slender hairs.

From all other larvae recorded in stored products, it may be distinguished by having densely spinose verrucae on the thorax and abdomen (fig. 6) and four pairs of prolegs.

GEOMETRIDAE.

Body usually slender and cylindrical with abdominal segments much longer than thoracic. Thoracic legs well developed. Prolegs absent on third, fourth, and fifth abdominal segments, very rarely present in a rudimentary form on these segments; crochets biordinal and arranged in a mesoseries. Chaetotaxy as follows: only primary setae present above the level of the spiracle; below eta subprimaries are always found and vary in number from one (λ) to many.

As the larvae of no other family of the Lepidoptera have the prolegs reduced to two pairs (on 6 and 10), the vast majority of the GEOMETRIDAE can be assigned to their family at a glance.

Sterrhia inquinata (Scop.)

(Fig. 7).

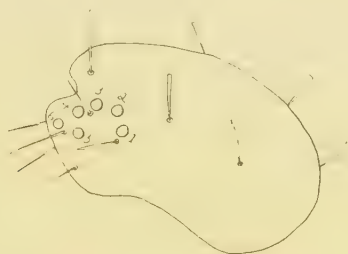


Fig. 7. *Sterrhia inquinata* (Scop.).—Left lateral view of head.

Mature Larva.—Length, 17–20 mm.; breadth, 2–3 mm. Cuticle moderately pale yellowish-brown or greenish-brown with numerous small, irregularly shaped, pale reddish-brown patches; head dark brown. Surface—of dried specimens—with very dense, often confluent punctures which are one-third to one-half as coarse as an ocellus; head with punctures so frequently confluent that surface is coarsely rugose; surface of thorax and abdomen also with numerous large, moderately prominent, oval or irregular gibbosities. Setae of head, thorax, and abdomen occasionally long and slender but usually short (about four or five times as long as an ocellus), very stout, and feebly club-shaped. *Head* with six ocelli (fig. 7), the sixth equally distant from fourth and fifth and upper five arranged in a semicircle with caudal side open; seta vii between third and fourth ocelli. Adfrontals extending slightly more than two-thirds of distance to vertical triangle. *Spiracles* round, slightly projecting, and peritreme moderately dark brown; those of I and 6 8 about as large as ocelli and those of 1–5 about three-fourths as large. *Chaetotaxy* as follows: Kappa group of I bisetose, in a vertical line, separated from spiracle by

slightly more than three times the diameter of the peritreme, and separated from each other by less than the diameter of the spiracle. Pi group of I bisetose and of II-III unisetose, that of III being more caudal than lateral on leg swelling. Segments 1-7 with kappa distant from and directly behind spiracle, eight with kappa also distant but caudo-ventral to spiracle; one with rho and eta in a vertical line slightly anterior to spiracle; 2-5 with eta as in one but rho more anterior to spiracle than kappa is caudad; 6-7 with rho much nearer to spiracle, and eight with rho as in one but eta directly below spiracle.

Two blown specimens have been examined. *S. inquinata* is the only Geometrid known to be associated with stored products, and it may therefore be distinguished from all other species dealt with here by having prolegs only on the sixth and tenth abdominal segments.

AGROTIDAE.

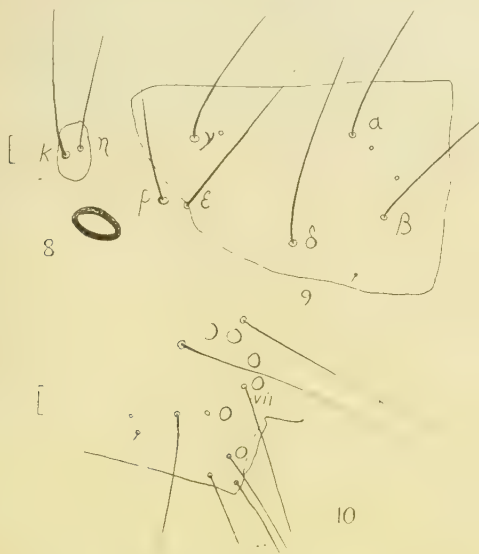
The larvae of this very large family are not easily defined. According to Fracker (1915), the genera may be divided into at least four distinct groups on whether the setae are primary or secondary, the crochets uniordinal or biordinal, etc. The species which have been found associated with stored products belong to Fracker's first group, a group which includes the vast majority of the species of the family. The larvae of this group possess the following combination of characters: "Larvae with primary setae only; prothorax with beta above level of alpha, epsilon associated with rho between delta and spiracle, Kappa and Pi groups each bisetose; mesothorax with alpha associated with beta, epsilon with rho, and kappa with eta, theta separate, Pi group unisetose; metathorax similar. Abdominal segments 1 to 6 and 8 with alpha above level of beta, rho above level of spiracle, epsilon, when present, smaller, and located cephalodorsad of spiracle, kappa and eta widely separated, mu present, Pi group consisting of three setae on most segments; sigma present; no other setae present except sometimes a few members of the tau group and sometimes gamma; segment 7 similar except that kappa is always much lower and closer to eta; segment 9 with alpha, beta, and rho forming a triangle, kappa, eta, mu, pi, and sigma present. Prolegs present on segments 5, 6, and 10, at least, and usually on segments 3 and 4; crochets arranged in a mesoseries, uniordinal except in some Plusiinae and others, in which the crochets are biordinal."

Apamea sordens (Hufn.)

(Figs. 8-10).

Mature Larva.—Length, 30-35 mm.; breadth, 4-5 mm. Cuticle pale olive-brown or grey-brown with setae and most of head and legs yellowish brown; mandibles and crochets dark reddish brown to nearly black; peritreme of spiracles black or nearly so; pinnaculæ dark olive brown to nearly black; thorax and abdomen with three complete longitudinal whitish or pale yellowish stripes, one on mid-dorsal line, a broader one on each side below spiracles, and a narrower and less distinct line between level of spiracles and mid-dorsal line. *Head* with front extending about half way to vertical triangle and lateral boundaries of adfrontals joining coronal suture at a point about three times as far from vertical triangle as from front. Each side with six distinct ocelli (fig. 10) of which the second is equidistant between first and third or sometimes slightly nearer to the first than to the third and the fifth is caudal to and between fourth and sixth which are very widely separated. Mandible with three large apical teeth. *Spiracles* of 8 large, obovate with vertical diameter distinctly greater than horizontal, and with peritreme evenly thickened and moderately strongly projecting; spiracles of 1-7 similar but slightly smaller; spiracles of I similar and as large as those of 8. *Legs* with front coxae nearly contiguous and middle and hind coxae only slightly more widely separated. Prolegs with crochets uniordinal and arranged in a mesoseries or single longitudinal row. *Chaetotaxy* as follows: Head

with frontal puncture nearly as caudal as frontal seta and much nearer to the latter than to caudal clypeal seta; puncture between setae i and ii only about half as far from i as from ii; seta vii near to and caudo-ventral to fourth ocellus. Prothorax (fig. 9) with beta dorsal to alpha, nearly as caudal as delta, and about as far from the latter as from alpha; epsilon nearly directly dorsal to rho and much nearer to the latter than to gamma which is as anterior as alpha; Kappa (fig. 8) bisetose with setae in a vertical or nearly vertical line and separated by a distance equal to thickness of peritreme of prothoracic spiracle. Pi of I bisetose with setae in a feebly oblique or nearly horizontal line; II-III unisetose; 1 bisetose with nu antero-lateral to pi; 2 trisetose with nu antero-lateral to pi and tau mesal and slightly anterior to pi; 3-6 trisetose with nu nearly directly anterior to pi and nearly as far from the latter as is tau; 7-9 unisetose. Ninth abdominal segment with alpha between and anterior to the beta but nearer to the latter than to rho; Kappa unisetose. Kappa and eta of 1-6 and 8 widely separated and in an oblique or nearly vertical line with kappa caudo-dorsal to eta and directly caudal to spiracle; kappa and eta of 7 much nearer together and in a nearly horizontal line well below spiracle. Rho of 1-8 directly dorsal to spiracle; epsilon opposite dorsal margin of spiracle and separated from spiracle by slightly less to slightly more than the diameter of the latter. Prosternum with a large, median, protrusible vesicle near anterior margin.



Figs. 8-10. *Apamea sordens* (Hufn.).—(8) Kappa group of prothorax. (9) Dorsal view of prothorax. (10) Ocellar region of head.

From the larvae of all other species dealt with here, which have the crochets of the prolegs arranged in longitudinal rows (mesoseries), this may be distinguished by having five pairs of prolegs and no secondary setae.

PYRALIDAE.

The chief distinguishing feature of this family is the bisetose Kappa group of the prothorax combined with the absence of secondary setae on all parts of the body.

the five well developed but short pairs of prolegs nearly always bearing bi- or tri-ordinal crochets which are arranged on the four anterior pairs in two transverse bands (CHRYSAUGINAE), a complete or nearly complete circle (PYRALINAE, PHYCITINAE, GALLERIINAE, etc.), or a penellipse (CRAMBINAE, PYRAUSTINAE). Eta and kappa of the first eight abdominal segments are apparently always closely associated. There are nearly always six ocelli except in a few specialised forms, e.g., *Pyralis*, *Galleria*, *Achroia*, etc., where they are reduced in number or are even absent. The epipharynx usually has three large sclerotised teeth on each side.

With the exception of *Etiella zinckenella* (Treit.), the species that are found associated with stored products may be placed in their appropriate subfamilies by means of the following key:

1. First four pairs of prolegs with crochets arranged in a penellipse. Eighth abdominal segment without a sclerotised ring enclosing a membranous area around base of seta rho.....CRAMBINAE
- First four pairs of prolegs with crochets arranged in a complete circle. Eighth abdominal segment with a distinct sclerotised ring enclosing a membranous area around base of seta rho.....2
2. Kappa setae of prothorax in a horizontal or feebly oblique line. First abdominal segment with a sclerotised ring enclosing a membranous area around base of seta rho. Pi group of meso- and metathorax sometimes bisetose...GALLERIINAE
- Kappa setae of prothorax in a vertical or nearly vertical line. First abdominal segment without a sclerotised ring enclosing a membranous area around base of seta rho. Pi group of meso- and metathorax always unisetose.....3
3. Mesothorax with a sclerotised ring enclosing a membranous area around base of seta rho PHYCITINAE
- Mesothorax without a sclerotised ring enclosing a membranous area around base of seta rho.....PYRALINAE

GALLERIINAE.

Although the larvae of only five species of GALLERIINAE belonging to four genera have been studied, it is abundantly clear that there exist in this subfamily two very distinct groups of genera. The chief differences between these groups are shown in the following table:

1. Pi group on meso- and metathorax bisetose. Head with less than six ocelli on each side; mandible (figs. 14-15) with three apical teeth and without a ventral, subapical tooth.....*Galleria*, *Achroia*
- Pi group on meso- and metathorax unisetose. Head with six ocelli on each side; mandible (fig. 16) with only two apical teeth but with a ventral, sublateral, subapical tooth.....*Aphomia*, *Corecya*

These striking differences in larval structure are correlated with notable differences in the structure of the apex of the tenth abdominal tergite (uncus) of the adult males. In *Galleria* and *Achroia* the apex of the uncus is armed only with two stout hooks, whereas in *Aphomia*, *Corecya*, and related genera the apex of the uncus is fringed with numerous coarse spines.

The rather specialised habits of *Galleria* and *Achroia* together with the obvious fact that these two genera must have been derived from forms possessing six ocelli on each side of the head of the larva would seem to suggest that the section of the subfamily containing these is the less primitive one. However, the evidence afforded by the structure of the mandibles and the possession of two Pi setae on the meso- and metathorax points to a contrary conclusion. The structure of the mandibles in *Galleria* and *Achroia* appears to be more primitive than that in *Aphomia*, etc., but probably little weight can be attached to structural differences in the mandibles as

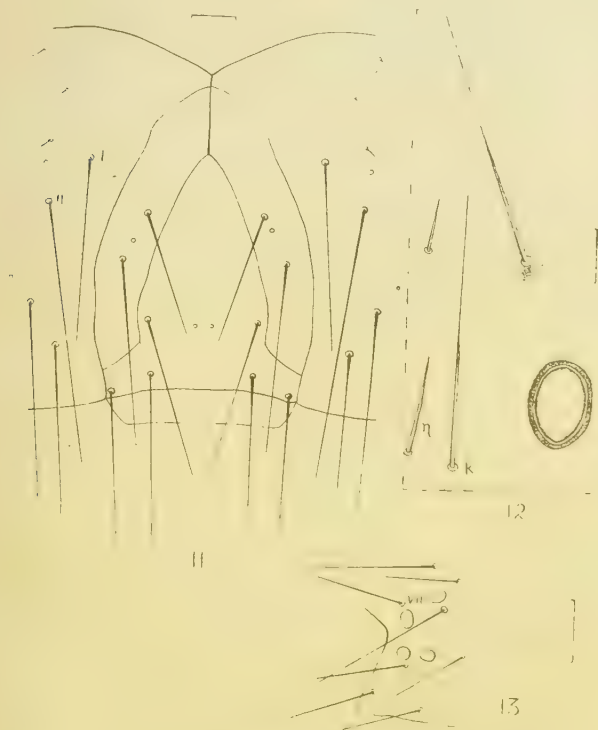
many instances are known of marked differences between the manibibles of species in the same genus. The primitive number of setae in the Pi group of the thorax is two, pi and nu. *Galleria* and *Achroia* are the only known genera of the PYRALIDAE with two Pi setae on the meso- and metathorax, and, as it is scarcely likely that they are derived from an ancestor which had already lost one of the Pi setae, it seems probable that *Galleria*, *Achroia*, and related genera are the most primitive of the GALLERIINAE and possibly also of the PYRALIDAE.

A difference in the number of ocelli does not appear to constitute evidence that can be in any way compared in its phylogenetic importance with a difference in the number of primary setae, the number of ocelli apparently being a highly plastic character.

The larvae of the GALLERIINAE as a whole—if the classification of the adult PYRALIDAE based almost entirely on wing venation be accepted—differ from those of all other subfamilies in having a ring around base of seta rho of the first as well as the eighth abdominal segment. Three of the four genera of GALLERIINAE examined have the crochets nearly uniordinal in the mature larvae.

Galleria mellonella (L.)

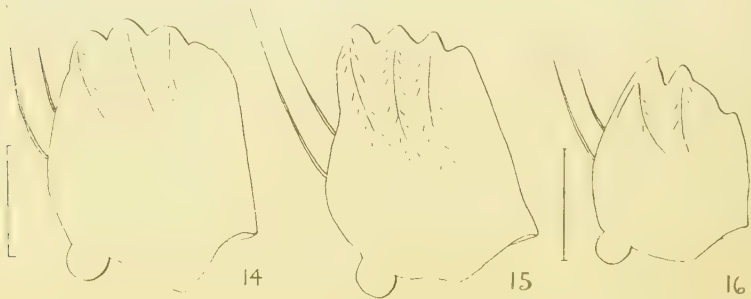
(Figs. 11-14).



Figs. 11-13. *Galleria mellonella* (L.).—(11) Head. (12) Spiracular region of eighth abdominal segment. (13) Ocellar region of head.

* According to Fracker (1915) and Forbes (1923) the CHRYSAUGINAE have the Pi group of the meso- and metathorax unisetose. Bruce & Melander (1932) and Gerasimov (1937) claim that the Pi group of the two caudal thoracic segments is bisetose in the CHRYSAUGINAE.

Mature Larva.—Length, 22–25 mm.; breadth, 4–5 mm. Cuticle moderately pale yellowish-brown or greyish-brown except as follows: setae, head, mouth-parts, sclerites of 1 and 10, peritreme of spiracles, parts of legs, and crochets darker and reddish-brown; head with extreme anterior part, meso-ventral margin, and apices of mandibles very dark brown or black; maxilla with cardo and stipes sometimes nearly black. Cuticle of non-sclerotised parts of thorax and abdomen with dense, microscopic, brown asperities. *Head* (fig. 11) with front extending more than two-thirds of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point which is about four or more times as far from front as from vertical triangle. Each side with only four distinct ocelli (fig. 13), first and second being fused together as well as third and fourth. Mandible (fig. 14) with three well developed apical teeth and without a ventral, subapical tooth. *Spiracles* of 8 (fig. 12) obovate with vertical diameter much greater than horizontal (12 : 9), nearly twice as large as those of 7 (12 : 7), and with caudal part of peritreme no thicker than anterior part; spiracles of 1–6 similar but no larger than those of 7; spiracles of 2–6 sometimes scarcely noticeably smaller than those of 1 and 7; spiracles of 1 similar but slightly smaller than those of 8. *Legs* with front coxae separated by about half breadth of a front coxa; middle and hind coxae about twice as widely separated as front. Prolegs with small crochets about two-thirds to four-fifths as long as large ones; four anterior pairs of prolegs with crochets arranged in a complete circle. *Chaetotaxy* (figs. 11–13) as follows: Head (fig. 11) with frontal puncture very nearly as caudal as frontal seta and much nearer to the latter than to caudal clypeal seta; setae i and ii about equally distant from the puncture between them; seta vii (fig. 13) directly dorsal or mesal to second (actually third plus fourth) ocellus. Pi group of I–III bisetose with setae in a horizontal line; 1–2 trisetose with setae in a nearly transverse line but with nu slightly anterior to pi and tau; 3–6 trisetose with nu antero-lateral to pi and approximately as far from pi as is tau, so that lines joining them would form an equilateral triangle; 7–8 bisetose with nu antero-lateral to pi, nu of 7 being slightly more lateral to pi than is nu of 8; 9 unisetose. Ninth abdominal segment with alpha between and anterior to beta and rho and scarcely nearer to beta than to rho; Kappa group with eta antero-dorsal to kappa and less than half as far from kappa as is eta, which is nearly ventral to kappa. Eta and kappa of 1–8 (fig. 12) in an oblique line with eta antero-dorsal to kappa. Dorsal setae of 1–8 without or only with very feebly marked pinnaculae.



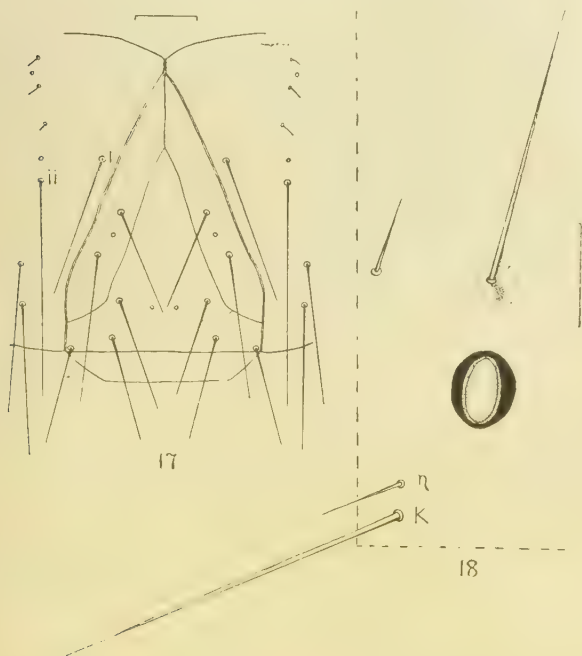
Figs. 14–16. Ventro-mesal view of mandibles of the GALLERIINAE. (14) *Galleria mellonella* (L.). (15) *Achroia grisella* (F.). (16) *Corcyra cephalonica* (Staint.).

Earlier Instars.—The smallest available larva is 9 mm. long and 1.8 mm. broad. It is similar to the mature larva but the boundaries of the adfrontals join the coronal suture at a point slightly less than three times as far from front as from vertical triangle.

This species and *Achroia grisella* (F.) are the only Pyralids dealt with here that have the Pi group of meso- and metathorax bisetose. *G. mellonella* is not closely related to *A. grisella*, from which it is easily distinguished by the presence of four distinct ocelli on each side of the head, the evenly thickened peritreme of the spiracles, and the position of eta antero-dorsal instead of directly dorsal to kappa on the first eight abdominal segments.

Achroia grisella (F.)

(Figs. 15, 17-18).



Figs. 17-18. *Achroia grisella* (F.).—(17) Head. (18) Spiracular region of eighth abdominal segment.

Mature Larva.—Length, 15-18 mm. ; breadth, 2.5-3.0 mm. Cuticle white or pale greyish-white except as follows : setae, head, mouth-parts, dorsal sclerites of I and sometimes also 10, parts of legs, and crochets pale to moderately dark reddish-brown ; head with extreme anterior region, meso-ventral margin opposite stipes and cardo, and apices of mandibles much darker red-brown to black ; peritreme of spiracles very dark brown or black. **Head** (fig. 17) with front extending two-thirds of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point about four times as far from front as from vertical triangle. Ocelli absent ; in a few specimens the cuticle is slightly modified and there appears to be a poorly developed lens in the usual position of the fourth ocellus, but the pigment normally lying beneath a lens is absent in all specimens examined. Mandible (fig. 15) with three well developed apical teeth, without a ventral subapical tooth, and with outer ventral

margin broadly and moderately deeply sinuate at apical third. *Spiracles* of 8 (fig. 18) obovate with vertical diameter much greater than horizontal, nearly twice as large as those of 7 (7.5 : 4.0), and with caudal part of peritreme distinctly thicker than anterior part; spiracles of 1-7 similar to those of 8 but much smaller and with caudal part of peritreme one and a half to twice as thick as anterior part, those of 1 and 7 being very slightly larger than those of 2-6; spiracles of 1 smaller than those of 8 (5.5 : 7.5) and with peritreme thickened as in those of 1-7. *Legs* with front coxae separated by a sixth or seventh of breadth of a front coxa; middle coxae four times and hind coxae five times as widely separated. Prolegs with small crochets only a third to a half as long as large crochets; four anterior pairs of prolegs with crochets arranged in a complete circle. *Chaetotaxy* (figs. 17-18) as follows: Head (fig. 17) with frontal puncture nearly as caudal as frontal seta and much nearer to the latter than to caudal clypeal seta; seta i twice as far as seta ii from puncture normally between them and i almost directly lateral to ii. Pi group of I-III bisetose with setae in a nearly horizontal line, but with anterior seta slightly more ventral than caudal seta; 1-2 trisetose with pi and tau in a transverse line, nu being anterior to both; 3-6 trisetose with nu antero-lateral to pi and about as far from pi as is tau so that lines joining them would form a nearly equilateral triangle; 7-8 bisetose with nu anterior and slightly lateral to pi; 9 unisetose. Ninth abdominal segment with alpha between and anterior to beta and rho and slightly nearer to rho than to beta; Kappa group with eta dorsal and slightly anterior to kappa and about a third as far from kappa as is eta, which is nearly directly ventral to kappa. Eta and kappa of 1-8 (fig. 18) in a vertical line, eta being directly dorsal to kappa. Dorsal setae of 1-8 without pinaculæ; sclerotised ring around base of seta rho of 1 and 8 often very indistinct, that of 1 being frequently absent, in which case the pigmented bar is sometimes scarcely visible.

Earlier Instars.—The smallest available larva is 6 mm. long, and it is identical in structure with the mature larva.

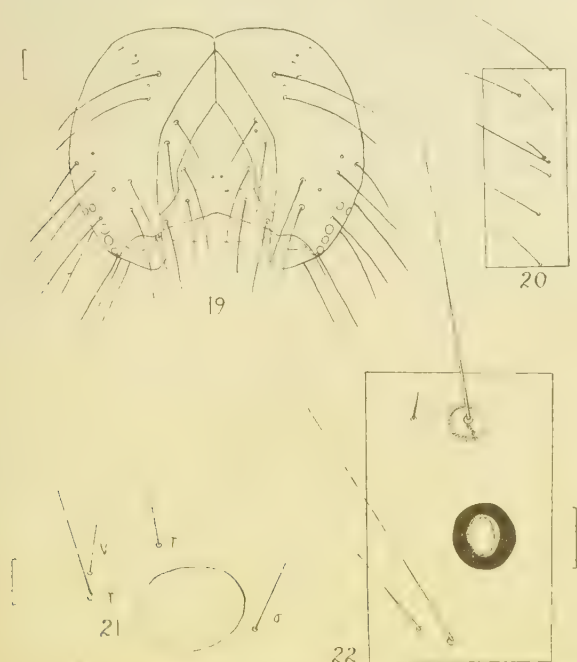
This species and *Galleria mellonella* (L.) are, as far as I am aware, the only two species of the subfamily GALLERIINAE that have the Pi and group of the meso- and metathorax bisetose instead of unisetose. Both species inhabit beehives, and the ocelli are reduced in number or absent. Of the two species, the blind *A. grisella* appears to be the more specialised for life inside hives. *A. grisella* may be distinguished from *G. mellonella* as follows: (1) mature larvae with body shorter and relatively more slender; (2) non-sclerotised parts of cuticle of thorax and abdomen with asperities very indistinct and of same colour as cuticle between them instead of being much darker; (3) head without ocelli instead of having four on each side; (4) mandible (fig. 15) with outer ventral margin broadly and moderately deeply sinuate at apical third; (5) peritreme of spiracles black or nearly so and with caudal part (at least of I and 1-7) distinctly thicker than anterior part, whereas in *G. mellonella* the peritreme is moderately pale brown and evenly thickened; (6) front coxae separated by a sixth or seventh of breadth of a front coxa instead of by about a half of breadth of coxa; (7) prolegs with small crochets one-third to one-half instead of two-thirds to four-fifths as long as large crochets; (8) seta ii of head much nearer to puncture normally between i and ii than is i which is nearly directly lateral to ii; (9) Kappa setae of prothorax in a line opposite ventral instead of dorsal margin of spiracle; (10) eta and kappa of 1-8 (fig. 18) in a vertical instead of an oblique or nearly horizontal line; and (11) Pi group of 7 with nu nearly directly anterior instead of nearly directly lateral to pi.

Aphomia sociella (L.).

(Figs. 19-22).

Mature Larva.—Length, 22-27 mm.; breadth, 3-4 mm. Cuticle pale yellow except as follows: most of head and pronotal sclerite pale yellowish-brown; anterior part of head, meso-ventral margin opposite stipes and cardo, and apices of mandibles

very dark brown to black ; setae, mouth-parts, parts of legs, and crochets moderately pale reddish-brown ; peritreme of spiracles black or nearly so. *Head* (fig. 19) with front extending slightly more than half of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point about three times as far from front as from vertical triangle. (In fig. 19 the coronal suture appears relatively shorter than it actually is due to the fact that the head is strongly curved downwards near base.) Each side with six well developed ocelli, of which first and second are nearly contiguous as are also third and fourth. Mandible similar to that of *Corexyra cephalonica* (fig. 16) ; with two large apical teeth and a smaller, ventral, subapical tooth the outer margin of which is mesal to the ventro-lateral margin of the mandible. *Spiracles* of 8 (fig. 22) nearly round with vertical diameter only very slightly greater than horizontal, slightly larger than those of 7 (6.5 : 5.0), and caudal part of peritreme, which is only slightly thicker than anterior part, about four times as thick as base of seta rho ; spiracles of 1 similar to those of 7 ; spiracles of 2-6 only very slightly smaller than



Figs. 19-22. *Aphomia sociella* (L.).—(19) Head. (20) Ninth abdominal segment. (21) Pi group of fourth abdominal segment. (22) Spiracular region of eighth abdominal segment.

those of 1 and 7 but otherwise similar ; spiracles of 1 similar to those of 8 but slightly larger. *Legs* with front coxae separated by about a sixth or seventh of breadth of a front coxa ; middle coxae about five times and hind coxae about six or seven times as widely separated. Prolegs with crochets feebly biordinal, the small crochets being about three-fourths or more as long as the large ones ; four anterior pairs of prolegs with crochets arranged in a complete circle. *Chaetotaxy* (figs. 19-22) as follows : Head (fig. 19) with frontal puncture nearly as caudal as frontal seta and much nearer to the

latter than to caudal clypeal seta; seta vii between second and third ocelli but much nearer to third than to second. Pi group of I bisetose with setae in a horizontal line; II-III unisetose; 1-2 trisetose with setae in a transverse line but with nu slightly anterior to pi and tau; 3-6 trisetose (fig. 21) with nu directly lateral to pi but in a few specimens (4 out of 23 examined) nu is also slightly but distinctly lateral to pi; tau of 3-6 three times as far from pi as is nu; 7-8 bisetose with nu nearly directly anterior and only slightly lateral to pi; 9 unisetose. Ninth abdominal segment with alpha between and anterior to beta and rho. Kappa group with eta only half as far from kappa as is mu and antero-dorsal instead of directly ventral to kappa. Eta and kappa of 1-8 in an oblique line with eta more dorsal than kappa. Dorsal and ventral setae of 1-8 without distinct pinnaculæ.

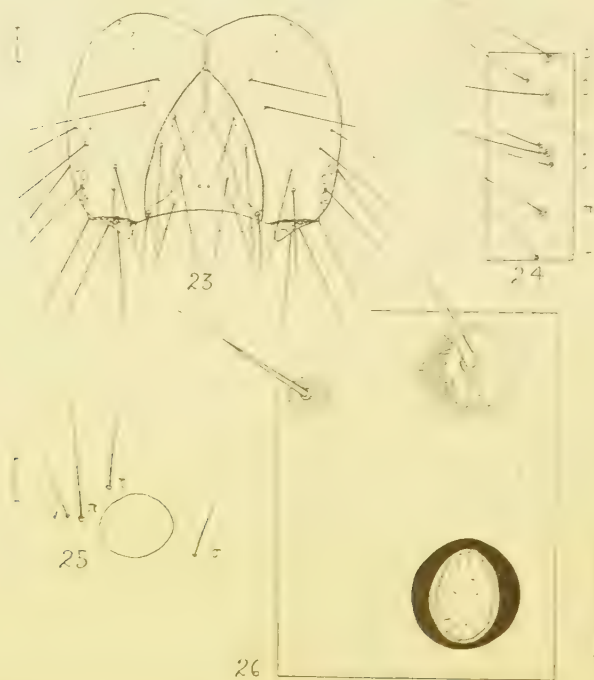
From all the species of the subfamily GALLERININAE dealt with here this may be easily distinguished by having the peritreme of the spiracles of the eighth abdominal segment four times as thick as the base of seta rho of the same segment.

In a few not quite fully grown larvae examined, the boundaries of the adfrontals join the coronal suture at a point only slightly nearer to vertical triangle than to front.

The descriptions and figures purporting to be of *A. sociella* given by Hofmann (1875) and Buckler (1901) evidently refer to another species, possibly *Aphomia gularis* (Zell.).

Aphomia gularis (Zell.).

(Figs. 23-26).



Figs. 23-26. *Aphomia gularis* (Zell.).—(23) Head. (24) Ninth abdominal segment. (25) Pi group of fourth abdominal segment. (26) Spiracular region of eighth abdominal segment.

Mature Larva.—Length, 25–30 mm.; breadth, 3–4 mm. Cuticle whitish or greyish-white except as follows: setae, most of head and mouth-parts, pronotal sclerite, parts of legs, and crochets moderately pale to dark reddish-brown; peritreme of spiracles black or nearly so; head with anterior margin, a large oval patch on each side adjacent to caudal margin, meso-ventral margin opposite stipes and cardo, and apices of mandibles black or at any rate much darker brown than other parts of head; pinnaculae of thorax and abdomen smoky brown. Non-sclerotised parts of thorax and abdomen densely set with oval or irregularly shaped, microscopic asperities which are pale brown; cuticle also with a few much larger, oval, sclerotised, feebly depressed areas. *Head* (fig. 23) with front extending half of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point only slightly nearer to vertical triangle than to front. Each side with six well developed ocelli, of which the third and fourth are very close together or even contiguous. Mandible similar to that of *Corcyra cephalonica* (fig. 16); with two large apical teeth and a smaller ventral, subapical tooth, the outer margin of which is mesal to the ventro-lateral margin of the mandible. *Spiracles* of 8 nearly round with vertical diameter only slightly greater than horizontal, slightly larger than those of 7 (6:5), and caudal part of peritreme, which is not or only very slightly thicker than anterior part, less than twice as thick as base of seta rho of same segment; spiracles of 1 similar to those of 7, and those of 2–6 only slightly smaller but otherwise similar to those of 1 and 7; spiracles of 1 as large or very slightly larger than those of 8 and with caudal part of peritreme distinctly thicker than anterior part. *Legs* with front coxae separated by about a sixth or seventh of breadth of a front coxa; middle coxae about four and hind coxae about six or seven times as widely separated as front. Prolegs with crochets feebly biordinal, the small crochets being two-thirds to three-fourths as long as the large ones; four anterior pairs of prolegs with crochets arranged in a complete circle. *Chaetotaxy* as follows. Head (fig. 23) with frontal puncture slightly but distinctly nearer to frontal than to caudal clypeal seta; seta vii between second and third ocelli but slightly nearer to third than to second. Pi group of I bisetose with setae arranged in a horizontal line; II–III unisetose; 1–2 trisetose with setae in a transverse line but with nu slightly anterior to pi and tau; 3–6 trisetose (fig. 25) with mu antero-lateral (almost directly lateral) to pi and half or less than half as far from pi as is tau; 7–8 bisetose with mu anterior and only slightly lateral to pi; 9 unisetose. Ninth abdominal segment (fig. 24) with alpha between and anterior to beta and rho but very slightly nearer to rho than to beta; Kappa group with mu only very slightly further from kappa than is eta and with all three setae on the same pinnaculum. Eta and kappa of 1–8 in an oblique line with eta anterior and slightly dorsal to kappa. Dorsal and most of ventral setae of 1–8 with distinct pinnaculae.

Earlier Instars.—The smallest available larvae are 7 mm. long, and they differ in no important particular from the mature larva. The cuticle of the non-sclerotised parts of the thorax and abdomen is more nearly white so that the dark pinnaculae are much more conspicuous than is the case in mature specimens.

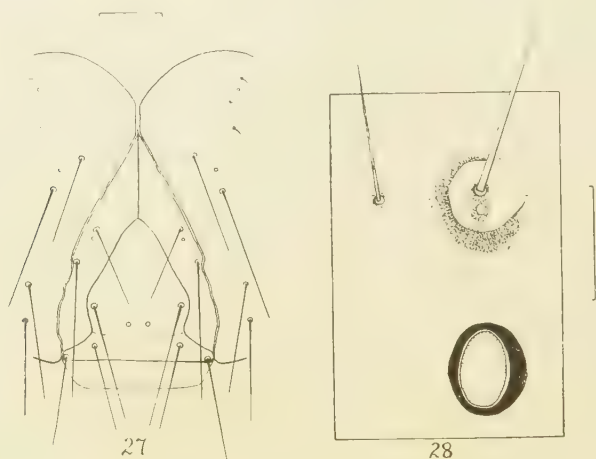
This species is very closely related to *Corcyra cephalonica*, and in fact it appears to be much more nearly related to the latter than to its congener, *Aphomia sociella* L. It may be distinguished from *C. cephalonica* as shown under the heading of the latter.

Corcyra cephalonica (Staint.).

(Figs. 16, 27–28).

Mature Larva.—Length, 15 mm.; breadth, 3 mm. Colour and structure nearly identical to *Aphomia gularis* (Zell.) except as follows: (1) cuticle of non-sclerotised parts of thorax and abdomen white instead of yellowish or greyish; (2) dorsal and lateral setae of first seven abdominal segments usually without pinnaculae but occasionally with rather indistinct pinnaculae; (3) head with boundaries of adfrontals

joining coronal suture at a point about twice as far from front as from vertical triangle; and (4) peritreme of abdominal spiracles with caudal part about twice as thick as anterior part instead of equally thick or only very slightly thicker.



Figs. 27-28. *Corcyra cephalonica* (Staint.).—(27) Head. (28) Spiracular region of eighth abdominal segment.

Earlier Instars.—The smallest available larvae are 6 mm. long. These are similar to the mature larvae except that the boundaries of the adfrontals join the coronal suture at a point much nearer to front than to vertical triangle, and the small crochets are only one-half instead of two-thirds or three-fourths as long as the large ones.

This species is difficult to distinguish from *Aphomia gularis*, particularly as most of the differences mentioned above are subject to considerable variation. For example, the differences between the two species as regards the point at which the boundaries of the adfrontals join the coronal suture does not hold good in larvae that are not quite fully grown. In practice it has been found that the majority of specimens of *Corcyra cephalonica* can be immediately distinguished from *A. gularis* by their much whiter cuticle, absence of distinct pinnaculæ on the first seven abdominal segments, and by the fact that the caudal part of the peritreme of the abdominal spiracles is distinctly thicker than the anterior part, being usually one and a half to twice as thick instead of very slightly or not at all thicker. The difference between the species as regards the relative thickness of the caudal and anterior parts of the peritreme of the abdominal spiracles appears to be a constant.

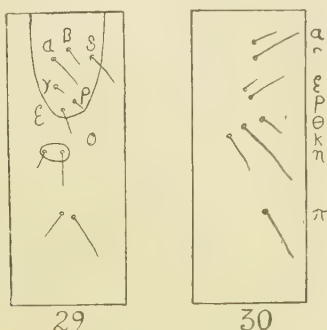
PHYCITINAE.

The larvae of this subfamily are easily distinguished from those of all others by having a sclerotised ring enclosing a membranous area around base of seta rho of the mesothorax. They are closely related to the PYRALINAE with which they agree in having the kappa setae of the prothorax in a vertical or nearly vertical line and the crochets of the four anterior pairs of prolegs arranged in complete circles and biordinal, the small ones being only about a third as long as the large ones. The epipharynx has three large sclerotised teeth on each side as appears to be usual in the PYRALIDAE. As mentioned below, the larval characters of *Etiella zinckenella* (Treit.) suggest that this species should be referred to another subfamily.

Etiella zinckenella (Treit.)

(Figs. 29-30).

No larvae of this species are available and the following description is based on that given by Forbes (1923).



Figs. 29-30. *Etiella zinckenella* (Treit.).—(29) Prothorax. (30) Mesothorax. (After Forbes.)

Cuticle apple-green, reddish, or brown; pinnaculae yellow with region immediately around base of setae black; head amber yellow with a brown posterior line; prothorax green with three pairs of black dots, the lateral ones being in a reddish shade. *Chaetotaxy* as follows: Prothorax (fig. 29) with beta slightly nearer to alpha than to delta and gamma very slightly nearer to epsilon than to alpha; rho distinctly nearer to epsilon than to gamma, being nearer to epsilon than is gamma to epsilon; Kappa setae in a horizontal line; Pi group bisetose with setae in a nearly horizontal line. Mesothorax without a sclerotised ring enclosing a membranous area around base of seta rho; Pi group unisetose.

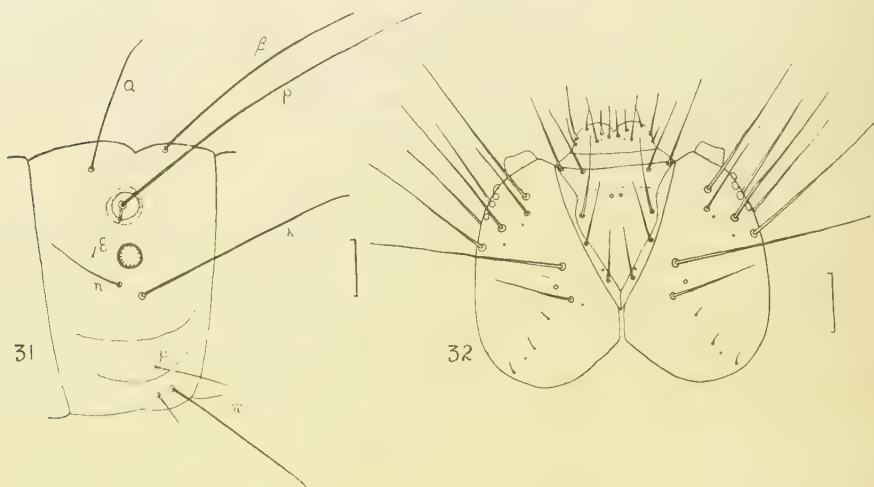
From all other Pyralids dealt with here it may be distinguished by having rho of the prothorax much nearer epsilon than is gamma to epsilon. If the larva described as that of *Etiella zinckenella* by Forbes (1923) has not been misidentified, the adult should be re-examined with a view to placing it in another subfamily. *E. zinckenella* differs strikingly from all other PHYCITINAE in having the Kappa setae of the prothorax in a horizontal instead of a vertical line and in not having a sclerotised ring enclosing a membranous area around base of seta rho of mesothorax.

Plodia interpunctella (Hbn.)

(Figs. 31-32).

Mature Larva.—Length, 10-13 mm.; breadth, 1.8-2.2 mm. Cuticle white except as follows: most of head and mouth-parts, claws and crochets moderately pale yellowish brown or reddish brown; head with meso-ventral margin opposite stipes and a small longitudinal patch on each side near base often very dark brown or black; setae, sclerites of I and 10, peritreme of spiracles, and parts of legs pale yellowish brown. *Head* (fig. 32) with front extending two-thirds of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point slightly less than twice as far from vertical triangle as from front. Each side usually with six distinct ocelli but occasionally with only five as first and second may be more or less fused together; in a few specimens examined the third and fourth are contiguous. Mandible with three distinct apical teeth, of which the middle one is the

largest; outer tooth as in *Ephestia cautella* (fig. 48). Spiracles of 8 round, slightly smaller to slightly larger than membranous area enclosed by sclerite around base of seta rho, one-fourth larger than those of 7, and peritreme feebly projecting and evenly thickened, being very slightly less thick than basal part of seta rho; spiracles of 7 similar to those of 8 but distinctly smaller; spiracles of 1-6 similar but very slightly smaller than those of 7; spiracles of 1 slightly smaller but otherwise similar to those of 8 and diameter about equal to distance between Kappa setae. Legs with front coxae separated by about two-thirds of diameter of a front coxa; middle and hind coxae separated by about their own breadths. Prolegs with crochets biordinal, the small crochets being about a third as long as the large ones; crochets of four anterior pairs of prolegs arranged in complete circles. *Chaetotaxy* as follows: Head (fig. 32) with frontal puncture equidistant between caudal clypeal and frontal seta or very slightly



Figs. 31-32. *Plodia interpunctella* (Hbn.).—(31) Eighth abdominal segment. (32) Head.

nearer the latter; seta vii antero-ventral and very near to second ocellus. Prothorax with beta only slightly nearer to alpha than to delta and gamma nearly twice as far from alpha as from epsilon (7:4). Pi group of I bisetose with setae in a nearly horizontal line; II-III unisetose; 1-2 trisetose with nu antero-lateral to pi, and tau more or less directly mesal to pi; 3-6 trisetose with nu antero-lateral to pi and very nearly as far from pi as is tau so that lines joining the three would form a nearly equilateral triangle; 7-8 bisetose with nu nearly directly anterior to pi; 9 bisetose with nu mesal and slightly anterior to pi. Ninth abdominal segment with alpha between and anterior to beta and rho but only about half as far from rho as from beta; Kappa group in a nearly vertical line with eta usually about half as far from kappa as is nu, but in many specimens the distance between the three setae is nearly equal; eta often slightly anterior to kappa. Eta and kappa of 1-7 in a nearly vertical line and of 8 in a distinctly oblique line. Epsilon of 8 separated from spiracle by a distance approximately equal to the diameter of the spiracle. Setae of II-III and 1-9 not arising from pinnaculæ; ring around base of seta rho of I and 8 sometimes feebly sclerotised and rather indistinct.

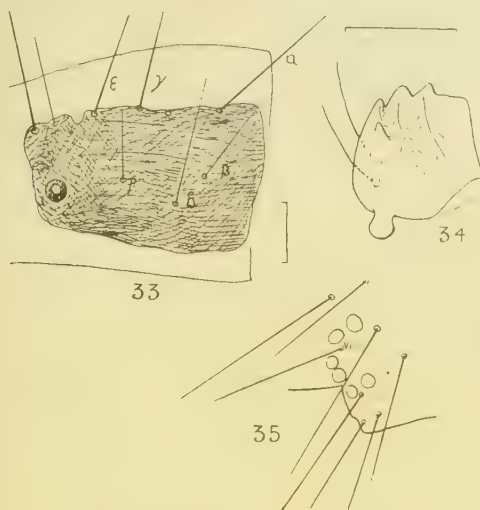
From all other PHYCITINÆ dealt with here which have the non-sclerotised parts of the cuticle white, *Plodia interpunctella* may be distinguished by having no pinnaculæ

on the meso- and metathorax and the first nine abdominal segments. It differs from all other PHYCITINAE dealt with here—with the possible exception of *Etiella zinckenella* (Treit.)—in having the front of the head extending two-thirds instead of approximately only one-half of the distance to the vertical triangle.

Cryptoblabes gnidiella (Mill.)

(Figs. 33–35).

Mature Larva.—Length, 11 mm.; breadth, 1.8 mm. Cuticle moderately dark grey-brown with faint purplish reflections in some lights except as follows: setae most of head and mouthparts, sclerite of I, peritreme of spiracles, legs, and crochets reddish-brown or yellowish-brown; head with a longitudinal black or nearly black patch on meso-ventral margin opposite stipes; pinnaculæ blackish-brown surrounded by paler areas. *Head* with front extending half way to vertical triangle and boundaries of adfrontals joining coronal suture at a point about three times as far from vertical triangle as from front. Each side with six distinct ocelli (fig. 35) of which the second is equidistant between first and third, and third and fourth are nearly contiguous. Mandible (fig. 34) with three distinct and well developed apical teeth; outer tooth



Figs. 33–35. *Cryptoblabes gnidiella* (Mill.).—(33) Prothorax. (34) Ventro-mesal view of right mandible. (35) Ocellar region of head.

with a small subapical notch or feebly developed tooth on ventral surface of third near outer margin. *Spiracles* of 8 round, nearly as large as membranous area enclosed by sclerotised ring around base of seta rho, and peritreme moderately strongly projecting evenly thickened, and dorsal rim about as thick as basal part of seta rho; spiracles of 1–7 similar but only slightly more than half as large; spiracles of I about as large as those of 8 and outside diameter of peritreme about equal to distance between kappa setae. *Legs* with hind coxae separated by slightly less than the diameter of a hind coxa (pro- and mesosternum are badly damaged in the single specimen available). *Prolegs* with crochets biordinal, the small crochets about a third as long as the large ones; four anterior pairs of prolegs with crochets arranged in a complete circle.

Chaetotaxy as follows: Head with frontal puncture slightly but distinctly nearer to frontal than to caudal clypeal seta; puncture between setae i and ii nearer to seta ii; seta vii (fig. 35) directly ventral to second ocellus. Prothorax (fig. 33) with dorsal sclerite extending laterally to join spiracular sclerite on a broad front; beta distinctly nearer to delta than to alpha, and gamma nearly twice as far from alpha as from epsilon. Pi group of I bisetose with setae in a nearly horizontal line; II-III unisetose; 1-2 trisetose with nu antero-lateral to pi and slightly nearer pi than is tau which is nearly directly mesal to the latter; 3-6 trisetose with nu directly anterior to pi and only about half as far from pi as is tau; 7 bisetose with nu nearly directly anterior and only slightly lateral to pi; 8 bisetose with nu anterior and only slightly mesal to pi; 9 bisetose with nu antero-mesal to pi. Ninth abdominal segment with alpha between and anterior to beta and rho but nearer to the latter; Kappa group with eta nearly directly anterior and only slightly dorsal to kappa, and mu nearly directly ventral to kappa and slightly further from the latter than is eta. Eta and kappa of 1-7 in an oblique line with eta antero-dorsal to kappa; 8 with eta and kappa in a nearly vertical line with kappa dorsal and only slightly caudal to eta. Epsilon of 1-8 minute, that of 8 being anterior to spiracle and separated from spiracle by a distance equal to about four or five diameters of the latter. Setae of I-III and 1-10 arising from pinnaculæ except epsilon of 1-8; each pinnaculum is surrounded by a broad area, which is paler than adjacent parts of cuticle, and, if this area be considered part of pinnaculum, Kappa and Pi groups of the abdomen have their setae on the same pinnaculum. Ring around base of seta rho of II and 8 well sclerotised and very distinct.

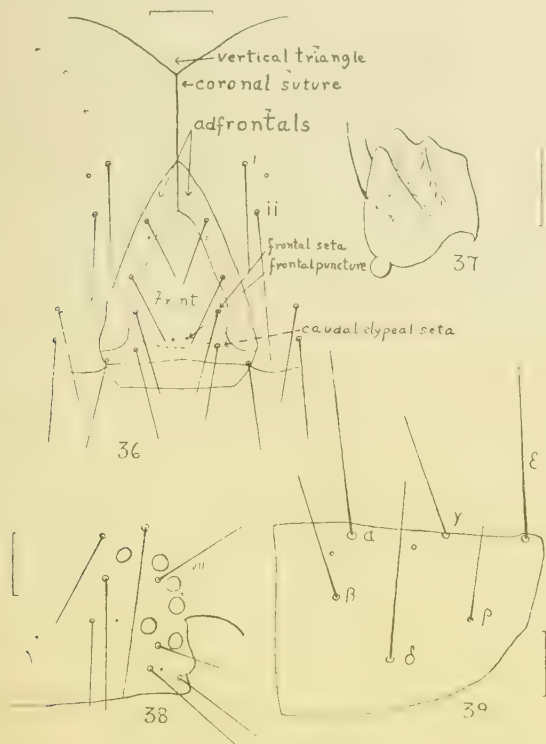
From all other members of the PHYCITINÆ dealt with here, it may be distinguished by having beta of the prothorax distinctly nearer to delta than to alpha. This is the only Pyralid known to me in which the pronotal sclerite is joined to the pre-spiracular sclerite along a broad front. Only a single blown specimen has been examined.

Acrobasis juglandis (Le Baron)

(Figs. 36-39).

Mature Larva.—Length, 16-18 mm.; breadth, 2 mm. Cuticle dark greyish brown with a slight purplish tinge except as follows: most of head and mouth-parts, legs and crochets moderately dark red-brown; meso-ventral margin of head black; setae and sclerites of I and 10 yellowish brown; peritreme of spiracles very dark brown to black or nearly black; and pinnaculæ moderately pale grey or yellowish brown. *Head* (fig. 36) with front extending half way to vertical triangle and boundaries of adfrontals joining coronal suture at a point less than twice as far from vertical triangle as from front. Each side with six distinct ocelli (fig. 38) of which the second is slightly but distinctly nearer to third than to first. Mandible (fig. 37) with three distinct apical teeth. Maxillary mala with both ventral apical spines forked distally as shown in *Acrobasis caryae* (fig. 43). *Spiracles* of 8 round or very feebly obovate, about a fifth or sixth larger than membranous area enclosed by sclerotised ring around base of seta rho, and peritreme at most only feebly projecting and with caudal part, which is as thick as basal part of seta rho, slightly thicker than anterior part; spiracles of 7 similar but only about two-thirds as large; spiracles of 1-6 similar to those of 7 but with those of 1 about a fifth larger; spiracles of 1 larger than those of 8 (4.8:3.5) and with outside diameter distinctly greater than distance between Kappa setae. *Legs* with front coxae separated by about a fifth of breadth of a front coxa; middle coxae about five and hind coxae about six or seven times as widely separated. Prolegs with crochets biordinal, the small crochets being about a third as long as large ones; four anterior pairs of prolegs with crochets arranged in a complete circle. *Chaetotaxy* as follows: Head (fig. 36) with frontal puncture equidistant between caudal, clypeal and frontal seta; puncture between setae i and ii slightly nearer i than ii; seta vii (fig. 38) between and ventral to second and third ocelli. Prothorax (fig. 39) with beta slightly nearer to alpha than to delta, and gamma

nearly as far from epsilon as from alpha (24.5 : 28.5). Pi group of I bisetose with setae in a horizontal line ; II-III unisetose ; 1-2 trisetose with nu antero-lateral to pi and about as far from pi as is tau, which is directly mesal to pi, pi and tau and sometimes also nu being on the same pinnaculum ; 3-6 trisetose with nu directly anterior or even slightly mesal to pi and about as far from pi as is tau, tau and nu being nearer together than either is to pi and all three being on the same pinnaculum ; 7 bisetose with nu anterior and slightly lateral to pi and usually on the same pinnaculum ; 8-9 bisetose with nu antero-mesal to pi and on same pinnaculum. Ninth abdominal segment with alpha between and anterior to beta and rho but distinctly nearer to beta than to rho, often arising from the same pinnaculum ; Kappa setae in a nearly vertical line with eta distinctly nearer to kappa than is mu, eta and kappa always and mu sometimes arising from the same pinnaculum. Eta and kappa of 1 in an oblique line with eta antero-dorsal to kappa ; 2-6 in a nearly horizontal line with kappa



Figs. 36-39. *Acrobasis juglandis* (Le Baron).—(36) Head. (37) Ventro-mesal view of right mandible. (38) Ocellar region. (39) Prothorax.

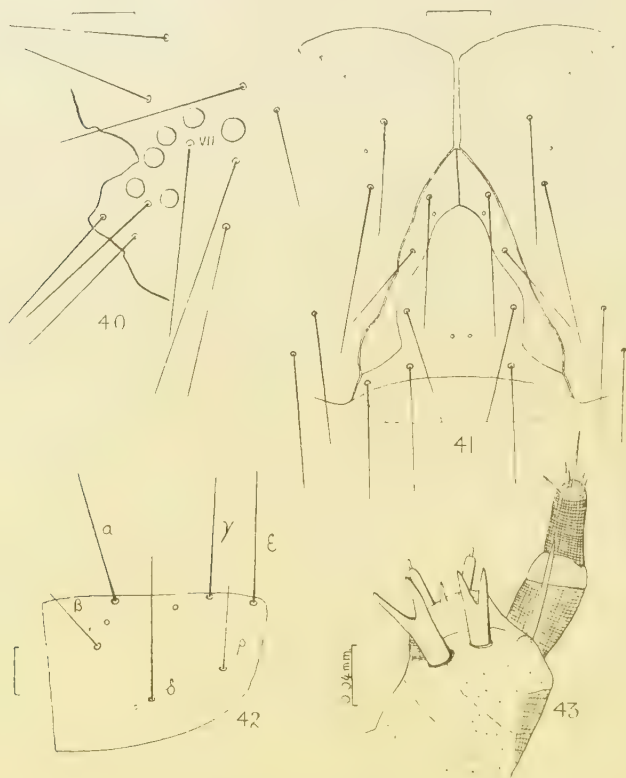
nearly directly caudal to eta ; 8 with kappa dorso-caudal to eta ; 1-8 with Kappa setae always arising from same pinnaculum. Epsilon of 1-8 represented by a minute puncture. Setae of I-III and 1-10 arising from pinnaculae, which are paler than adjacent parts of cuticle. Ring around base of seta rho of II and 8 broad and well sclerotised. Non-sclerotised parts of cuticle of thorax and abdomen with dense, microscopic asperities.

This species is closely related to *Acrobasis caryae* from which it may be distinguished as shown under the heading of *A. caryae*. Both species of *Acrobasis* differ from all other Pyralids considered in this paper by having the two ventral spines of the maxillary mala forked at apex.

The above description is based on four apparently mature larvae preserved in alcohol. These larvae were determined as *A. juglandis* by Dr. C. Heinrich.

Acrobasis caryae, Grote.

(Figs. 40-43).



Figs. 40-43. *Acrobasis caryae*, Grote.—(40) Ocellar region. (41) Head. (42) Prothorax. (43) Maxillary mala from dorsal view.

Mature Larva.—Length, 17 mm.; breadth, 2 mm. Cuticle (of specimens preserved in spirit) moderately pale yellow-brown or grey brown; head reddish-brown and other sclerotised parts of cuticle pale yellowish-brown except peritreme of spiracles which is very dark brown. According to Forbes (1923) living larvae are "... greenish gray, with dark brown head, shining yellow-green cervical shield, and light brown subdorsal plate on mesothorax." Structurally very similar to *Acrobasis juglandis* (Le Baron) but differing principally as follows: (1) head (fig. 41) with seta i no nearer than ii to puncture between them; (2) prothorax

(fig. 42) with gamma twice as far from alpha as from epsilon, whereas in *A. juglandis* gamma is only slightly further from alpha than from epsilon (fig. 39); (3) Pi group of 8 with nu directly anterior or only very slightly mesal to pi, whereas in *A. juglandis* nu is distinctly antero-mesal to pi; and (4) alpha of 9 nearer to rho than to beta on at least one side (2 specimens) or nearer to rho than to beta on both sides (2 specimens).

Four apparently mature larvae preserved in alcohol were examined. These larvae were determined as *A. caryae* by Dr. C. Heinrich. Of the differences given above between this species and *A. juglandis*, the position of seta gamma of the prothorax in relation to alpha and epsilon is the most conspicuous. The position of the posterior adfrontal seta varies slightly in both species, but in *A. caryae* it is sometimes distinctly caudal to the front.

Ephestia, Guenée.

The four species of *Ephestia* which have been examined by me are all very similar in structure. The mature larvae vary considerably in size and colour, but no differences have been found with regard to these characteristics, which in practice are of much use in distinguishing the species, though large specimens of *E. sericarium* (*kühniella*) are larger than any of *E. cautella* or *E. elutella*. The description given immediately below applies to the larvae of all four species, and the distinguishing features of each being listed under the heading of the particular species.

Mature Larva (in alcohol).—Cuticle white or pale yellowish white (pinkish in live specimens; very pale greenish in some *E. sericarium*) except as follows: setae, most of head and mouth-parts, sclerites of I and 10, peritreme of spiracles, parts of legs, and crochets moderately pale to moderately dark yellowish-brown; head often reddish-brown and nearly always with two black or very dark brown patches on each side, one on meso-ventral margin opposite stipes and cardo and one adjacent to caudal margin; pinnaculæ and sclerotised ring around rho of II and 8 usually dark grey-brown, but pinnaculum of beta of 9 usually yellowish brown like sclerite of 10. *Head* (figs. 44, 49) with front extending one-half or slightly more than one-half (*E. cautella*) of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point two or three times as far from vertical triangle as from front. Each side with six distinct ocelli (fig. 45) of which the second is nearer to the first than to the third or equidistant between first and third. Mandible (figs. 57–58) with three large apical teeth of which the third (normally the most lateral tooth) is sometimes slightly mesal (*E. sericarium*), the outer margin of the mandible—when viewed ventro-mesally—being in these instances part of the second or largest tooth. Maxillary mala (fig. 46) with both ventral spines simply pointed and not forked at apex. *Spiracles* of 8 round or nearly so, slightly smaller to slightly larger (*E. sericarium*, *E. cautella*) or distinctly smaller (*E. elutella*) than membranous area enclosed by sclerotised ring around base of seta rho, and peritreme evenly thickened and rather strongly projecting with dorsal rim much narrower and sides about twice as thick as basal part of seta rho; spiracles of 7 similar to those of 8 but only one-half to three-fifths as large; spiracles of 1–6 similar, those of 1 and 7 being sometimes slightly larger than those of 2–6; spiracles of 1 slightly smaller than those of 8. *Legs* with front coxae separated by about one-third or slightly more of breadth of a front coxa; middle coxae nearly twice and hind coxae two to three times as widely separated as front. Prolegs with crochets biordinal, the small crochets being about a third as long as large ones; crochets of four anterior pairs of prolegs arranged in complete circles. *Chaetotaxy* as follows: Head (figs. 44–49) with frontal puncture about equidistant between frontal and caudal clypeal seta or slightly nearer the latter; puncture between setae i and ii usually equidistant between these setae, but sometimes slightly nearer to i than to ii; seta vii ventral to second ocellus and caudal to third (fig. 45). Prothorax

with gamma twice or slightly less than twice as far from alpha as from epsilon; beta always slightly nearer to alpha than to delta, but in some specimens of *E. elutella* beta is twice as far from delta as from alpha. Pi group of I bisetose with setae in a nearly horizontal line; II-III unisetose; 1-2 trisetose with nu antero-lateral to pi and about as far from pi as is tau which is directly mesal to pi; 3-6 trisetose with nu antero-lateral to pi except in mature specimens of *E. sericarium* where it is directly anterior or even antero-mesal to pi, nu being in nearly all instances slightly nearer to pi than is tau; 7 bisetose with nu anterior and slightly lateral to pi; 8 bisetose with nu antero-lateral (*E. sericarium*), directly anterior or even very slightly mesal (*E. elutella*) or distinctly antero-mesal (*E. cautella*) to pi; 9 bisetose with nu mesal and slightly anterior to pi. Ninth abdominal segment with alpha anterior and slightly dorsal to rho and on same pinnaculum as the latter; Kappa setae with eta antero-dorsal (sometimes nearly directly dorsal) to kappa and slightly nearer to kappa than is eta, which is directly ventral to kappa; all three kappa setae often arising from the same pinnaculum, but sometimes with only eta and kappa on the same pinnaculum, and, more rarely, with each of these arising from a different pinnaculum. Eta and kappa of 1-7 in a vertical or nearly vertical line with kappa ventral to eta and sometimes also slightly caudal; 8 with eta and kappa in an oblique line, kappa being caudo-ventral to eta; kappa and eta of 1-8 often arising from same pinnaculum. Epsilon of 1-8 distinct and not arising from a pinnaculum; 8 with epsilon separated from spiracle by slightly less to three or more times the diameter of the spiracle. Thorax with Alpha, Beta, Rho, Kappa, and Pi arising from pinnaculae; abdomen similar except that epsilon never and Pi seldom arise from pinnaculae. Ring around base of seta rho of II and 8 broad and well sclerotised.

First Instar.—The first-instar larvae of three species (*E. cautella*, *E. sericarium* and *E. elutella*) have been examined. The first instar differs from the later instars in that mu is absent on the abdomen, theta on the meso- and metathorax, and in *E. elutella* theta is never present on the eighth abdominal segment. The pinnaculae of II-III and 1-9 are not developed, but the ring around rho of II and 8 is usually sufficiently well sclerotised to be distinct. The crochets are uniordinal instead of biordinal, and each proleg has 6-7 instead of 40-60 crochets. The first instar larvae of these three species may be distinguished as follows:—

1. Eighth abdominal segment with seta epsilon separated from spiracle by a distance equal to very slightly more, or to distinctly less, than the diameter of the spiracle..... *E. cautella* (Wlk.)

Eighth abdominal segment with seta epsilon separated from the spiracle by a distance equal to much more than the diameter of the latter.....2

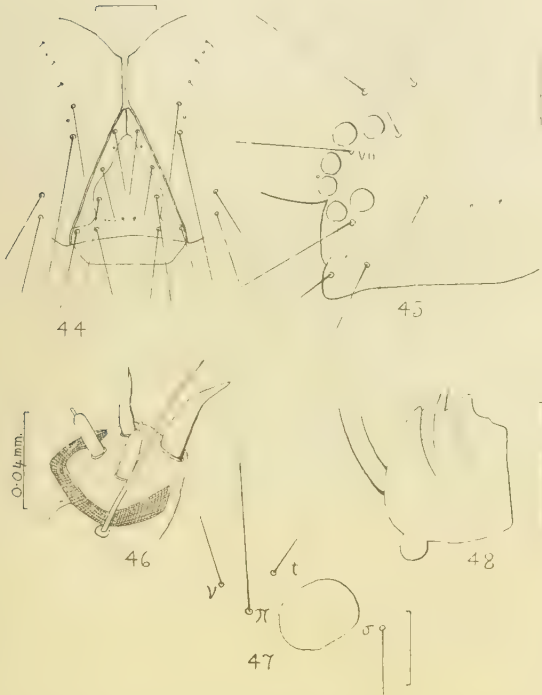
2. Mandible, when viewed ventro-mesally, with outer ventral tooth not forming part of outer margin of mandible but displaced mesally so that this margin is part of second or largest tooth. Spiracle of prothorax with diameter slightly greater than distance between Kappa setae.....*E. sericarium* (Scott)

Mandible, when viewed ventro-mesally, with lateral margin of third or outer tooth forming the lateral ventral margin of the mandible. Spiracle of prothorax with diameter slightly less than distance between Kappa setae.....
E. elutella (Hbn.)

Comparative Notes.—Any larva (excluding first-instar larvae) found on stored food which has a large sclerotised ring enclosing a membranous area at base of seta rho of mesothorax combined with a white or nearly white cuticle with darker and conspicuous pinnaculae is a species of *Ephesia*.

Ephestia cautella (Walker)

(Figs. 44-48, 53).

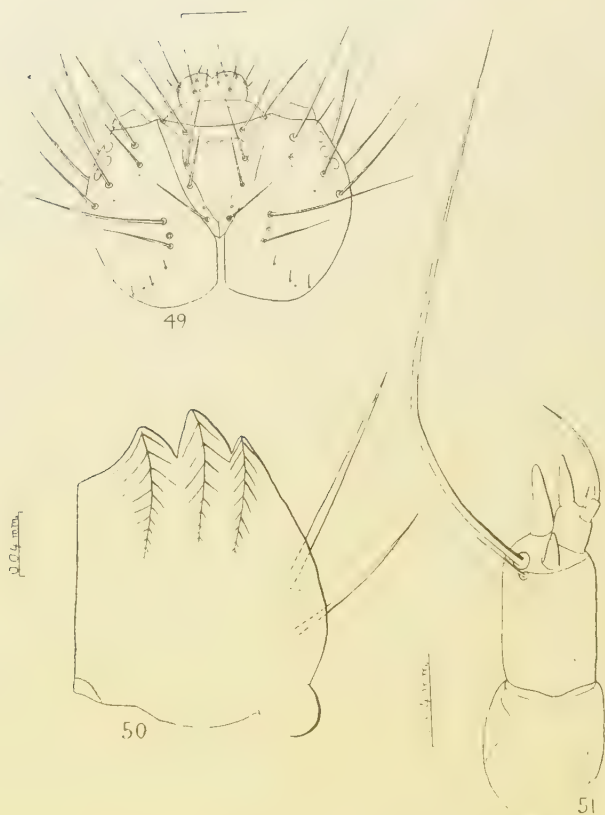


Figs. 44-48. *Ephestia cautella* (Walker).—(44) Head. (45) Ocellar region. (46) Dorso-lateral view of maxillary mala. (47) Pi group of fourth abdominal segment. (48) Ventro-mesal view of right mandible.

Mature Larva.—Length, 12-14 mm.; breadth, 1.8-2.0 mm. Specimens preserved in alcohol are usually distinctly darker and more yellowish or greyish white than the other species dealt with here. All instars may be distinguished from *E. sericarium* and *E. elutella* by having epsilon of 8 separated from the spiracle by distinctly less (rarely very slightly more) than the diameter of the latter instead of by nearly two to three or more diameters. Nu of the Pi group of 8 is distinctly mesal to pi, whereas in the other species it is distinctly lateral, only rarely being very slightly mesal in *E. elutella*. Nu of 3-6 is always distinctly antero-lateral to pi, whereas in fully grown larvae of *E. sericarium* nu is directly anterior or even slightly mesal to pi. The mandibles are similar to those of *E. elutella* and differ from those of *E. sericarium* as described under the heading of the latter species.

Ephestia figulilella, Gregson.

(Figs. 49-51).

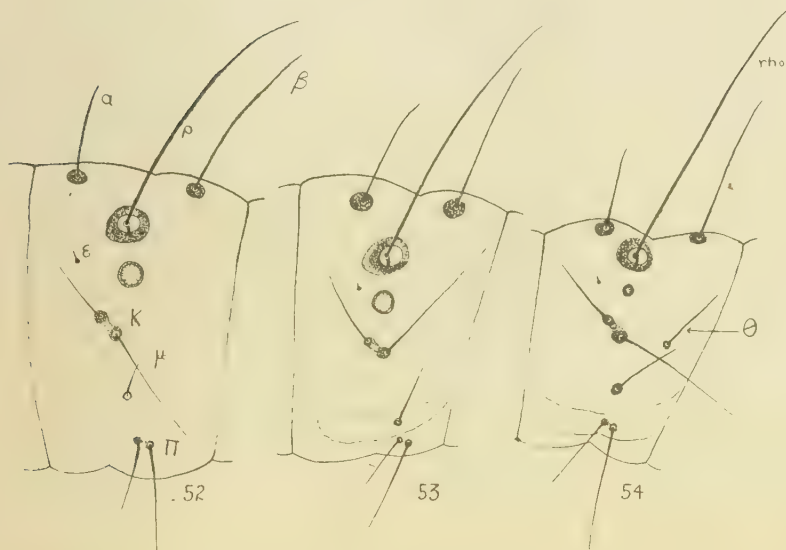


Figs. 49-51. *Ephestia figulilella*, Gregson.—(49) Head. (50) Meso-ventral view of left mandible. (51) Antenna.

Only a single bred specimen has been examined, which is 8 mm. long and 1.3 mm. broad. It is very close to *E. cautella*, and, until more specimens are available, cannot be satisfactorily distinguished from the latter species. The pinnaculæ of the abdominal setae are more feebly pigmented than in *E. cautella*, and epsilon of 8 is separated from the spiracle by a distance about equal to the diameter of the spiracle, whereas in *E. cautella* epsilon is nearly always separated from the spiracle by distinctly less than the diameter of the latter. The puncture between setae i and ii of the head is relatively much larger in *E. figulilella* than *E. cautella*.

Ephestia sericarium (Scott)

(Figs. 52, 56, 58).

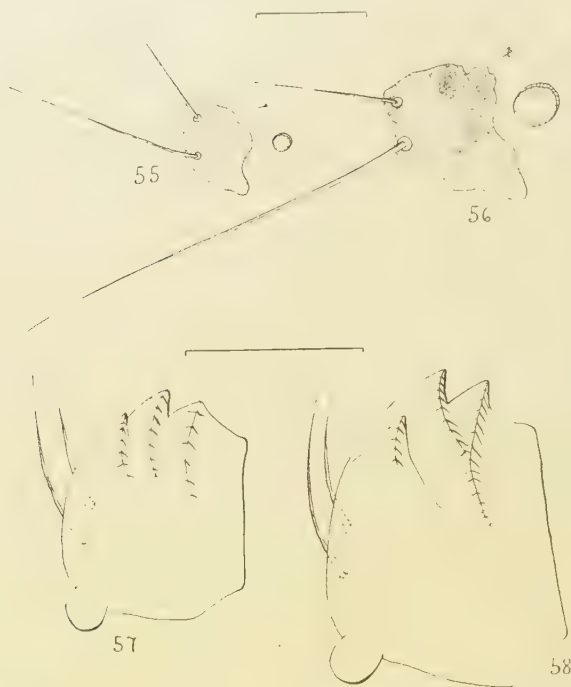


Figs. 52-54.—(52) Lateral view of eighth abdominal segment of *Ephestia sericarium* (Scott). (53) Same of *E. cautella* (Walker). (54) Same of *E. elutella* (Hbn.).

Mature Larva.—Length, 15-20 mm; breadth, 2-3 mm. All instars may be distinguished from *E. cautella*, *E. figulilella*, and *E. elutella* by having the third (normally the outer) tooth of the mandible (fig. 58) subventral and more mesal than is usual so that when the mandible is viewed meso-ventrally its outer margin is part of the second or largest tooth instead of being part of the third tooth. From *E. cautella* and *E. figulilella*, it is also distinguished by having epsilon of 8 separated from the spiracle by two to three diameters of the latter instead of only by one.

Ephestia clutella (Hbn.)

(Figs. 54-55, 57).



Figs. 55-58. (55) Spiracle and Kappa group of prothorax of *Ephestia clutella* (Hbn.). (56) Same of *E. sericarium* (Scott). (57) Ventro-mesal view of right mandible of *E. clutella*. (58) Same of *E. sericarium*.

Mature Larva.—Length, 10-15 mm.; breadth, 1.0-1.5 mm. Identical with *E. sericarium* except as follows: (1) mandible (fig. 57) with lateral margin of outer or third tooth forming part of outer ventral margin of mandible; (2) prothorax with diameter of spiracular opening distinctly less than distance between Kappa setae (fig. 55); (3) spiracle of eighth abdominal segment of mature or nearly mature larvae (fig. 54) not more than two-thirds as broad as membranous area enclosed by sclerotised ring around base of seta rho; (4) eighth abdominal segment with nu anterior and slightly mesal to pi, whereas in *E. sericarium* the fully grown larva has nu either directly anterior or antero-lateral to pi, nu being mesal to pi only occasionally in the earlier instars of the latter species; and (5) nu of 3-6 always antero-lateral to pi, whereas in fully grown larvae of *E. sericarium* nu is directly anterior or even antero-lateral to pi. In many specimens of *E. clutella* theta is present on either the right or left side of the eighth abdominal segment, and in a few specimens it is present on both sides. Intermediate instars of *E. clutella* cannot be easily distinguished from those of *E. sericarium* without examining the mandibles.

PYRALINAE.

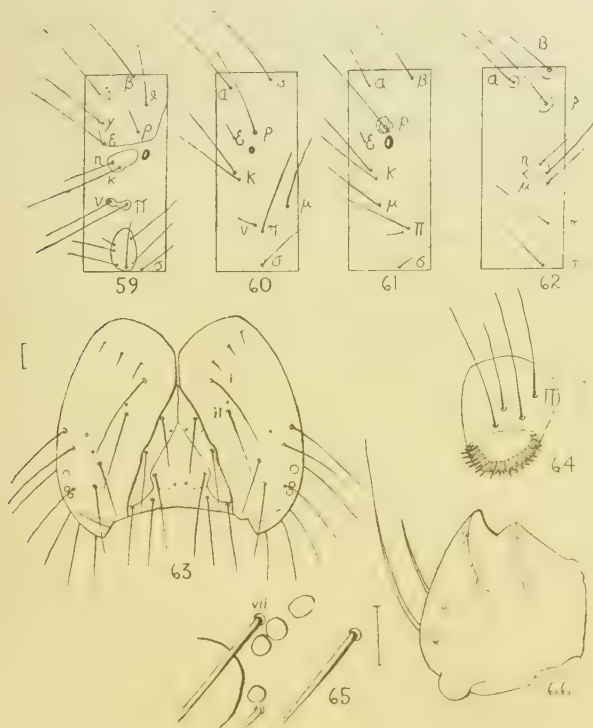
The larvae of this subfamily are very nearly related to those of the PHYCITINAE, and Fracker (1915) and other writers have been unable to distinguish them from the

PHYCITINAE as a whole. The presence of a sclerotised ring around the base of seta rho only on the eighth abdominal segment will serve to distinguish them from the PHYCITINAE, which, as far as is known, always have a sclerotised ring around the base of seta rho of the mesothorax as well as around the base of seta rho of the eighth abdominal segment. The PYRALINAE are similar to the PHYCITINAE in having the crochets of the four anterior pairs of prolegs biordinal (in the later instars) and arranged in a complete circle. In the PYRALINAE the large crochets are three or four times as long as the small ones.

Pyralis farinalis (L.)

(Figs. 59-66).

Mature Larva.—Length, 20-25 mm.; breadth, 3-4 mm. Cuticle whitish except as follows: setae, head, pronotal sclerite, parts of legs, and crochets moderately pale brown, the head and mandibles being distinctly reddish-brown; dorsal and lateral sclerites of tenth abdominal segment pale brown; apical part of mandibles, latero-caudal margin of head, and meso-ventral part opposite cardo usually black or nearly so; peritreme of spiracles always black; non-sclerotised parts of thorax and abdomen



Figs. 59-66. *Pyralis farinalis* (L.).— 59) Prothorax. 60) Seventh abdominal segment. 61) Eighth abdominal segment. 62) Ninth abdominal segment. 63) Head. 64) 11 group of tenth abdominal segment. 65) Ocellar region. 66) Ventro-mesal view of right mandible.

densely and regularly set with small (about as broad as seta epsilon of abdomen), flat-topped asperities which are usually brown or blackish-brown anteriorly and caudally so that thorax and first abdominal segment as well as caudal three or four abdominal segments appear greyish, the intermediate segments being distinctly paler. *Head* (fig. 63) with front extending about half of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point about half way between front and vertical triangle. Each side with only four distinct ocelli (fig. 65); the first and second ocelli are fused together and the fifth is usually absent but is sometimes barely distinguishable. *Mandible* (fig. 66) with two large apical teeth and with a slight subapical notch (not a distinct tooth) on ventral ridge of large lateral tooth. *Spiracles* of 8 obovate with vertical diameter distinctly greater than horizontal, twice as long as those of 7, and middle caudal part of peritreme about twice as broad as anterior part; spiracles of 1-7 very broadly oval with vertical diameter only slightly greater than horizontal, those of 1 and 7 being slightly larger than intermediate spiracles, and middle caudal peritreme of each two to three times as broad as middle anterior part; spiracles of I similar to those of 8 but very slightly smaller. *Legs* with front coxae separated by about one-fifth breadth of a front coxa; middle coxae about four times and hind coxae about six times as widely separated as front. Prolegs with crochets biordinal, the small crochets only a third or fourth as long as the large ones, and those of four anterior pairs of prolegs arranged in a complete circle. *Chaetotaxy* as follows: *Head* (fig. 63) with frontal puncture scarcely nearer to frontal seta than to caudal clypeal seta; seta vii (fig. 65) antero-dorsal to second (actually third as first and second are fused) ocellus. *Pi* group of I bisetose with setae in a horizontal line; II-III unisetose; 1-2 trisetose with setae in a transverse line but with nu slightly anterior to pi and tau; 3-6 trisetose with nu antero-lateral to pi and nearer to pi than is tau; 7 bisetose with nu antero-lateral to pi; 8 bisetose with nu anterior and slightly mesal to pi; 9 unisetose; 10 as shown in fig. 64. Ninth (fig. 62) with alpha anterior to and between beta and rho; Kappa group with eta antero-dorsal to kappa and mu nearly directly ventral (or lateral) to kappa, eta and mu being about equally far from kappa and on the same pinacula.

First Instar.—Length, 0.82 mm.; breadth, 0.13 mm. shortly after hatching. Head with inner sutures of adfrontal area not visible. Coxae of front legs contiguous; prolegs with crochets uniordinal and much reduced in number, there being about nine to ten on prolegs of 3-6. Rho of 8 apparently without a sclerotised circle around its base. Mu and theta are absent. *Pi* group of 1-6 appears to be bi- instead of trisetose, but the material at hand is not sufficiently well preserved to be certain of this. One larva of an intermediate instar (12 mm. long) is available. This larva is similar to the mature larva, but the boundaries of the adfrontals join coronal suture distinctly before midway point between front and vertical triangle.

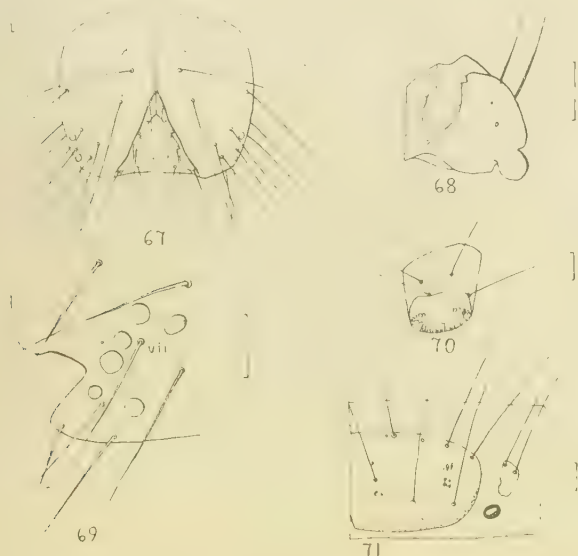
From the other PYRALINAE dealt with here, this may be distinguished by having only four ocelli on each side of the head and by having the outer boundaries of the adfrontals joining the coronal suture at a point about half way between front and vertical triangle.

Hypsopygia costalis (F.)

(Figs. 67-71).

Mature Larva.—Length, 15-17 mm.; breadth, 2-3 mm. Cuticle pale brown to black. Head moderately pale reddish-brown with a few irregular, usually longitudinal, dark brown patches on each side; apical part of mandibles and meso-antennae, margin very dark brown to black. Pronotal sclerite, legs, crochets, and setae yellowish to reddish-brown. Peritreme of spiracles dark brown to black. Thorax and abdomen very variable in colour but usually yellowish brown or olive-brown with dorsal and ventral surface very densely mottled with dark olivaceous to black

patches; non-sclerotised parts of thorax and abdomen very densely and regularly set with flat-topped, irregularly hexagonal, feebly elevated, microscopic asperities. *Head* (fig. 67) with front extending slightly more than one-third of distance to vertical triangle and boundaries of adfrontals joining coronal suture at a point about three times as far from vertical triangle as from front. Each side with six ocelli (fig. 69).



Figs. 67-71. *Hypsopygia costalis* (F.).—(67) Head. (68) Ventro-mesal view of left mandible. (69) Ocellar region. (70) Pi group of tenth abdominal segment. (71) Prothorax.

Mandible (fig. 68) with two moderately developed apical teeth and with a large but appressed, bifid, subapical, ventral tooth. *Spiracles* of 8 obovate with vertical diameter distinctly greater than horizontal (6:4), much longer than spiracles of 7 (6:4), and with caudal margin only distinctly thicker than anterior; spiracles of 1-7 slightly more broadly oval than those of 8 and with caudal margin of each noticeably thicker than anterior margin; spiracles of 1 and 7 are slightly but distinctly larger than intermediate ones; spiracles of I similar to those of 8. *Legs* with front coxae nearly contiguous, separated by a seventh or less of breadth of a front coxa; middle coxae about two or three times and hind coxae about three or four times as widely separated as front ones. Prolegs with crochets biordinal, the small crochets only a fourth as long as the large ones, and those of four anterior pairs of prolegs arranged in a complete circle. *Chaetotaxy* similar to that of *Pyrallis farinalis* except as already mentioned in the key. In addition, Pi group of 3-6 has nu slightly further from pi than is tau.

Earlier Instars.—The smallest larva available is 8 mm. long. This specimen is similar to the mature larva, but the spiracles are more broadly oval and the cuticle of the thorax and abdomen is considerably paler than appears to be usual in fully grown specimens.

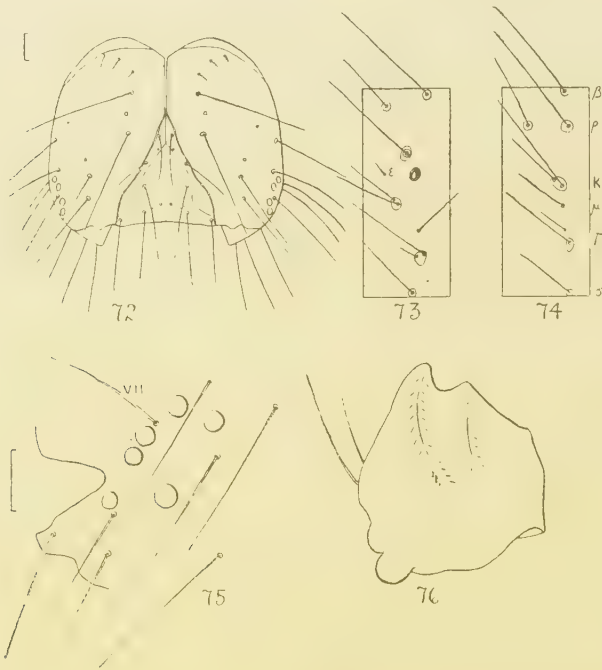
In colour and general appearance this larva resembles that of *Aglossa caprealis* (Hbn.) from which, however, it may be easily distinguished by the unisetose instead

the bisetose P₁ group of 9, the position of seta vii on the head, and the large, appressed, subapical, ventral tooth on the mandible.

Aglossa pinguinalis (L.)

(Figs. 72-76).

Mature Larva.—Length, 20-35 mm.; breadth, 2.5-4.0 mm. Cuticle rather variable in colour but usually as follows: head, mouth-parts, dorsal sclerites of I and 10, parts of legs, crochets, and setae yellowish-brown to moderately pale reddish-brown; apices of mandibles and peritreme of spiracles black or nearly so; thorax and abdomen greyish-white to nearly black, the thorax usually being distinctly darker than the abdomen; non-sclerotised parts very densely, regularly, microscopically asperate and with larger, oval, sclerotised depressions which form irregular but usually symmetrical patterns. Thorax and abdomen of some specimens moderately dark olive-brown and occasionally also with a distinct reddish tint. *Head* (fig. 72) with front extending very nearly half way to vertical triangle and lateral boundaries of adfrontals joining coronal suture at a point slightly less than twice as far from vertical



Figs. 72-76. *Aglossa pinguinalis* (L.).—(72) Head. (73) Eighth abdominal segment. (74) Ninth abdominal segment. (75) Ocellar region. (76) Ventro-mesal view of right mandible.

triangle as from front. Each side with six ocelli (fig. 75). Mandible (fig. 76) with two moderately well developed apical teeth; outer ventral margin deeply and broadly sinuate before base. *Spiracles* of 8 broadly oval with vertical diameter slightly but distinctly greater than horizontal, nearly twice as large as those of 7, and with caudal part of peritreme one and a half to two times as broad as anterior part;

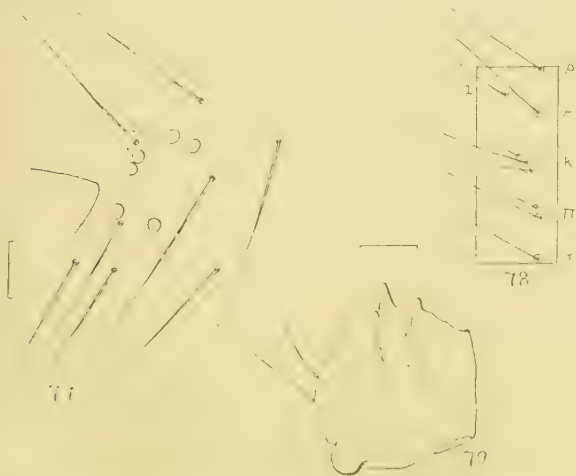
spiracles of 1-7 nearly round, those of 2-7 being slightly smaller than those of 1; spiracles of 1 similar but slightly larger than those of 8. Legs with front coxae separated by about a third breadth of a front coxa and middle and hind coxae separated by about breadth of coxae. Prolegs with crochets biordinal, the small crochets only a fourth or third as long as large ones, and those of four anterior pairs of prolegs arranged in a complete circle. *Chaetotaxy* as follows: Head (fig. 72) with frontal puncture slightly nearer to caudal clypeal seta than to frontal seta; seta vii between second and third ocelli but slightly nearer third than second. Pi group of I bisetose with setae in a horizontal line; II-III unisetose; 1-2 trisetose with setae in a transverse line but with nu slightly anterior to pi and tau; 3-6 trisetose with nu antero-lateral to pi and distinctly nearer to pi than is tau to pi; 7 bisetose with nu lateral and slightly anterior to pi; 8 bisetose with nu anterior and slightly mesal to pi; 9 (fig. 74) bisetose with nu lateral and very slightly anterior to pi; 10 with caudal setae more lateral as well as more mesal than anterior setae. Ninth (fig. 74) with alpha more or less directly anterior to rho; mu directly ventral to kappa and much further from the latter than is eta which is antero-dorsal to kappa; eta and kappa on same pinnaculum.

The bisetose Pi group of the ninth abdominal segment will serve to distinguish this larva from the other species of PYRALINAE dealt with here except *Aglossa caprealis* (Hbn.), but from the latter it is easily distinguished as shown in the key. The deep and broad sinuation near base of outer ventral margin of the mandible is an important diagnostic character for this species.

Aglossa caprealis (Hbn.)

(Figs. 77-79).

Mature Larva.—Length, 25 mm.; breadth, 3 mm. Colour similar to that of *Hypsopygia costalis* (F.) but often with a distinct bronzy lustre. Structure and chaetotaxy essentially similar to that of *A. pinguinalis* except as noted in the key. The spiracles are less broadly oval than in *A. pinguinalis* and the ventral diameter of



Figs. 77-79. *Aglossa caprealis* (Hbn.) —77, Ocellar region. (78) Ninth abdominal segment. (79) Ventro-mesal view of right mandible.

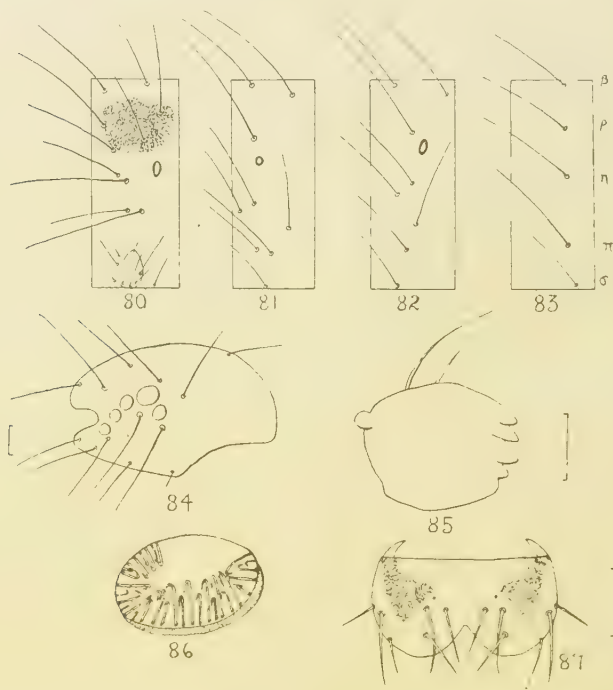
each is considerable greater than the horizontal. Only one blown specimen has been examined, and it is not possible to compare the arrangement of the Pi group of 10 with that of *A. pinguinalis*.

CRAMBINAE.

The larvae of this sub-family cannot easily be characterised. According to Fracker (1915), they may be divided into two distinct groups as follows: (1) kappa and mu of 9 absent or extremely minute and eta large and not associated with other setae, Pi group of II unisetose, and crochets triordinal and arranged in a complete circle; and (2) similar to above but with crochets biordinal and arranged in a penellipse. From the PYRAUSTINAE the latter group of the CRAMBINAE can only be distinguished by having biordinal instead of triordinal crochets, a character which is subject to great variation even within the same species and cannot therefore be considered to be satisfactory for separating two subfamilies.

Euchromius ocella (Haw.)

(Figs. 80-87).



Figs. 80-87. *Euchromius ocella* (Haw.).—(80) Prothorax. (81) Seventh abdominal segment. (82) Eighth abdominal segment. (83) Ninth abdominal segment. (84) Left side of head. (85) Ventro-mesal view of right mandible. (86) Diagrammatic view of crochets of fourth abdominal proleg. (87) Labrum.

The larvae presumed here to be that of *Euchromius ocella* (Haw.) has triordinal crochets arranged in a penellipse. It is remarkable in having not only kappa and mu absent on the ninth abdominal segment but also alpha. This is apparently the only known larva in the superfamily Pyralidoidea (*sensu* Fracker) in which alpha of 9 is lost.

Mature Larva.—Length, 14 mm.; breadth, 3.5 mm. Cuticle pale yellowish-white except as follows: dorsal surface of head black with seven large pale yellowish patches, one on middle of front, one each side between frontal suture and ocelli, one each side directly behind the latter near hind margin, and one each side partly enclosed by ocelli; ventral surface of head with a few irregular dark markings, the more conspicuous of which is a mesal, oblong, black patch on each side opposite cardo; mandibles black or very dark brown but other mouthparts pale brown; pronotum with a large, broadly oval, black patch on each side (fig. 80); spiracles with peritreme black or very dark brown; setae brown but with Pi group and sigma of 3-6 black or nearly so. Head with front extending to caudal fourth and adfrontals extending nearly to vertical triangle so that coronal suture is only about as long as breadth of largest ocellus. Each side with five well developed ocelli and one rudimentary ocellus arranged as shown in fig. 84. Spiracles of 8 obovate with vertical diameter much greater than horizontal and nearly twice as large as those of 7; spiracles of 1-7 nearly round and approximately equal in size; spiracles of 1 nearly as large as those of 8 and obovate with vertical diameter distinctly greater than horizontal. Legs with coxae of I contiguous, of II separated by about a third breadth of middle coxa, and of III separated by half breadth of hind coxa. Prolegs with crochets usually biordinal, occasionally triordinal, and arranged in a penellipse (fig. 86). *Chaetotaxy* as shown in figs. 80-84. Head with frontal puncture nearly as caudal as frontal seta and very much more distant from caudal clypeal seta than from frontal seta. Pi group of I bisetose with setae in a horizontal line; II-III unisetose; 1 bisetose; 2 trisetose with setae forming an equilateral triangle the apex of which is caudal; 3-6 trisetose with nu anterior and only slightly mesal to pi and about as far from pi as from tau, nu being directly lateral (or dorsal) to tau; 7 bisetose with the two setae in a longitudinal row; 8-9 unisetose, ninth (fig. 83) with alpha, kappa, and mu absent and eta large and not associated with other seta.

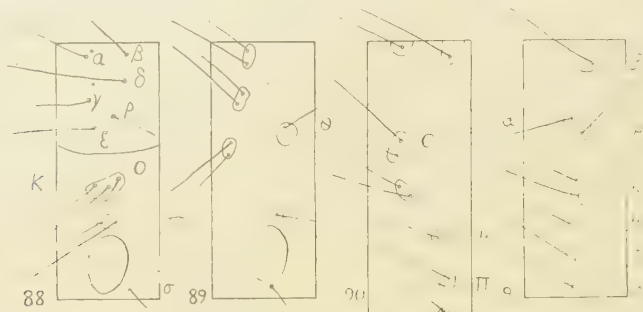
The above description is based on a single larva (presumed to be this species because *E. ocella* is the only species of CRAMBINAE known to be associated with stored food) which appears to be mature. It was found in a warehouse in Cheshire; Frodsham, ii.1943 (*J. M. Holborn*). *E. ocella* is the only species dealt with here which has the crochets arranged in a penellipse and lacks alpha, kappa, and mu on the ninth abdominal segment.

TORTRICIDAE.

The larvae of this family have the front extending one-fourth to three-fourths of the distance to the vertical triangle and the adfrontals reach or nearly reach the vertical triangle. There are six distinct ocelli on each side. The spiracles are round or broadly oval. Prolegs are always present on segments 3-6 and 10, and the four anterior pairs have the crochets arranged in complete circles, the crochets being either uni- or biordinal. An anal fork is often present. The Kappa group of the prothorax is always trisetose, and Pi of the eighth abdominal segment is always bisetose except in the Phaloninae where it is unisetose. Seta rho of the eighth abdominal segment is directly anterior to the spiracle except in a few rare cases.

The larvae are structurally very similar to the GELECHIIDAE and OECOPHORIDAE. However, only a few genera, e.g., *Nothris*, *Hypsolophus*, *Dasytoma*, etc., of the latter families have rho of the eighth abdominal segment directly anterior to the spiracle and, when this is the case, Pi of 8 is apparently always unisetose. Most of the GELECHIIDAE and OECOPHORIDAE have Pi of 8 unisetose, but exceptions are known, e.g., *Depressaria*. On 9 the beta setae are close together, often on the same pinnaculum whereas in the GELECHIIDAE and OECOPHORIDAE these setae are usually rather widely separated, seldom being on the same pinnaculum. Many genera of both the TORTRICIDAE and GELECHIIDAE have a well developed anal fork.

The larva of the codling moth, *E. pomonella* (L.) and related species of *Enarmonia* are sometimes found in warehouses, having been brought in with fruits and seeds. They may be distinguished from all other species dealt with here by possessing the following combination of characters: Kappa of prothorax trisetose; rho of 8 directly anterior to spiracle; Pi of 8 bisetose; and anal fork absent. *E. nigricana* (F.) has not been seen, but it is included in the key on characters given by Fracker (1915).



Figs. 88-91. *Enarmonia pomonella* (L.).—(88) Prothorax. (89) Mesothorax. (90) Eighth abdominal segment. (91) Ninth abdominal segment.

GELECHIIDAE.

The distinguishing features of this family have been summarised by Fracker (1915) and more fully by Benander (1937). The single Gelechiid, *Sitotroga cerealella*, Oliv., considered in this paper is an extremely specialised form adapted to feeding inside grain kernels where all instars except the first are found. The mature larva is 4-7 mm. long, strongly curved, with thorax much stouter than abdomen, which is gradually narrowed behind, and white with head pale brown and mandibles moderately dark reddish brown. From all other moth larvae associated with stored products it may be distinguished by its short, narrow, and often very indistinct prolegs, each of which has only two widely separated crochets.

COSMOPTERYGIDAE.

Detailed descriptions of the larvae of this family are too few to make it possible to select a character or a combination of characters which will serve to distinguish the larvae from those of all other families. The characterisation of the family given by Fracker (1915) excludes in nearly every particular *Pyroderces rileyi*.

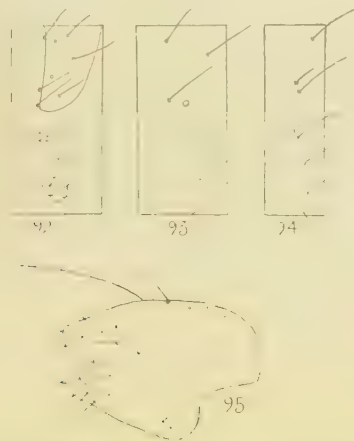
Pyroderces rileyi (Wals.)

(Figs. 92-95).

The description given below is based on that of Busck (1917) and Heinrich (1921) and on the illustrations given by these two authors.

Mature Larva.—Length, 7-8 mm. Cuticle deep wine red except as follows: setae and sclerite of 10 pale brown; head pale brown with blackish mouth-parts; pronotal sclerite strongly sclerotised and dark brown. **Head** with front extending about four-fifths of distance to vertical triangle; adfrontals extending to vertical triangle. Epipharynx with three large spines on each side. Mandible with four large, acute, apical teeth and a fifth less well developed, apically rounded, mesal tooth. Each side with six distinct ocelli. **Legs** normal. **Prolegs** with crochets unevenly bifurcinal and those of four anterior pairs arranged in a complete circle, each proleg

having 20-24 crochets. *Chaetotaxy* as follows: Head with frontal puncture far removed from caudal clypeal seta and nearly opposite frontal seta; puncture between setae i and ii about three times as far from ii as from i; seta vii directly ventral to second ocellus and caudal to third. Prothorax with beta slightly nearer to alpha than to delta and very slightly less caudal than delta; gamma three times as far from alpha as from epsilon; rho more or less equally distant from gamma and epsilon and further from both than epsilon is to gamma; Kappa group with eta nearly directly dorsal to kappa and theta caudo-dorsal to kappa. Pi group of I bisetose with setae in a horizontal line; II-III unisetose; 1-6 trisetose, m of 3-6 being antero-lateral to pi; 8-9 unisetose. Ninth abdominal segment (fig. 94) with alpha antero-dorsal to rho and much nearer to the latter than to beta; beta setae nearer to each other than to alpha; Kappa group with eta antero-dorsal to kappa and only a third as far from the



Figs. 92-95. *Pyroderces rileyi* (Wals.).—(92) Prothorax. (93) Eighth abdominal segment. (94) Ninth abdominal segment. (95) Left view of head. (After Heinrich.)

latter as is mu which is nearly directly ventral to kappa. Eta and kappa of 1-8 in a nearly vertical line with kappa ventral and also sometimes slightly caudal to eta. Rho of 8 (fig. 93) nearly directly anterior to spiracle and rho of 1-7 dorsal to spiracle; 1-8 with epsilon absent. Pinnaculæ absent or indistinct.

From all other larvae dealt with in this paper which have Kappa of the prothorax trisetose and eta and kappa of the abdomen adjacent, this may be distinguished by having eta of I directly dorsal to kappa and Pi of 8-9 unisetose instead of bisetose.

OECOPHORIDAE.

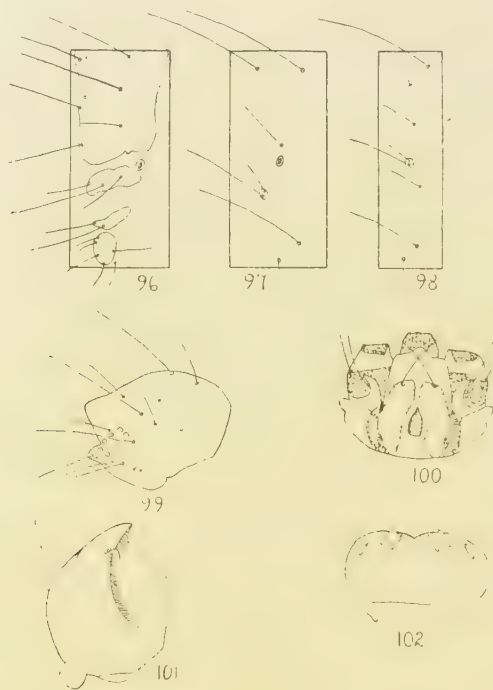
Head with six ocelli on each side except in *Holmannophila* and *Endrosis* which have four and two respectively. Adfrontals nearly always extending to vertical triangle, but in all instars of *Endrosis* and other genera ending considerably before vertical triangle. Epipharynx with three large spines on each side. Labium sometimes (*Anchonomia*, *Endrosis*, *Dasycera*) with a median basal pit. Spiracles round or oval with vertical diameter greater than horizontal. Spiracles of 8 sometimes two or three times as large as those of 7. Thoracic legs always well developed. Prolegs short,

stout, and well developed; crochets in a complete circle and usually biordinal except in the first one or two instars where they are uniordinal. Anal fork absent. Chaetotaxy as follows: Kappa of I trisetose with setae usually arranged in a horizontal line. Rho of 1-8 dorsal to spiracle, often very slightly antero-dorsal. Kappa and eta of 1-8 are close together and often, as in *Anchonoma*, *Endrosis* and *Hofmannophila*, arranged in a vertical row below and slightly anterior to spiracle. Pi of 8 unisetose. Alpha of 9 more lateral than beta but closer to beta than to rho.

Anchonoma xeraula, Meyr.

(Figs. 96-102).

No larvae of this species have been seen. The description given below is based on that of Heinrich (1920).



Figs. 96-102. *Anchonoma xeraula*, Meyr.—(96) Prothorax. (97) Eighth abdominal segment. (98) Ninth abdominal segment. (99) Left side of head. (100) Ventral view of labium to show postmental pit. (101) Ventro-mesal view of right mandible. (102) Ventral view of labrum. (After Heinrich.)

Mature Larva.—Length, 22-23 mm.; breadth, 2.0-2.5 mm. Cuticle white except as follows: Setae whitish yellow. Head blackish-brown, paler brown in ocellar, sub-ocellar, frontal, and adfrontal areas; mandibles paler brown, except at tip and along ridges, than dark parts of head; mentum blackish brown; and other

sclerotised areas of labial and maxillary parts yellow-brown. Prothorax with dorsal, pre-spiracular, and Pi sclerites evenly dark brown. Mesothorax with a brown sclerite bearing a minute seta on each side on antero-dorsal intersegmental area; sclerotised area about alpha slightly brownish. Abdomen with sclerite of 10 yellowish-brown. Legs with sclerotised areas brownish-yellow to dark brown; front margin of coxae blackish; prolegs with crochets pale brown. Spiracles rimmed with black. *Head* with front extending slightly less than half of distance to vertical triangle and lateral boundaries of adfrontals joining coronal suture at a point about three times as far from vertical triangle as from front. Each side with six distinct ocelli (fig. 99). Mandible (fig. 101) with a single large apical tooth and a subapical notch or rudimentary tooth on ventral side of large tooth. Labium (fig. 100) with a large, obovate, concave sclerotisation on submentum. *Spiracles* broadly oval, those of 8 twice as large as those of 1-7 and approximately as large as those of I. *Legs* normal. Prolegs with crochets unevenly and irregularly triordinal; four anterior pairs with crochets arranged in complete circles and each with 45-50 crochets. *Chaetotaxy* as follows: Head with frontal puncture slightly nearer to frontal than to caudal clypeal seta; puncture between setae i and ii much nearer to ii than to i; seta vii (fig. 99) near and directly dorsal to third ocellus. Prothorax (fig. 96) with beta very slightly more caudal than delta and nearer to the latter than to alpha; gamma only slightly nearer to alpha than to epsilon; rho nearly as far from epsilon as from gamma and nearly as distant from the two latter as they are from each other; Kappa setae with eta and kappa in a nearly horizontal line with eta nearer to kappa than is theta which is caudo-dorsal to kappa. Pi group of I bisetose with setae in a nearly horizontal line; II-III unisetose; 3-6 trisetose with nu antero-mesal to pi; 7 bisetose; 8-9 unisetose. Ninth abdominal segment (fig. 98) between and anterior to rho and beta but distinctly nearer the latter; Kappa setae in a nearly vertical line, kappa and eta being on same pinnaculum and eta only about a fifth as far from kappa as is mu. Eta and kappa of 1-8 (fig. 97) in a vertical or nearly vertical line with eta dorsal to kappa and both on same pinnaculum or tubercle.

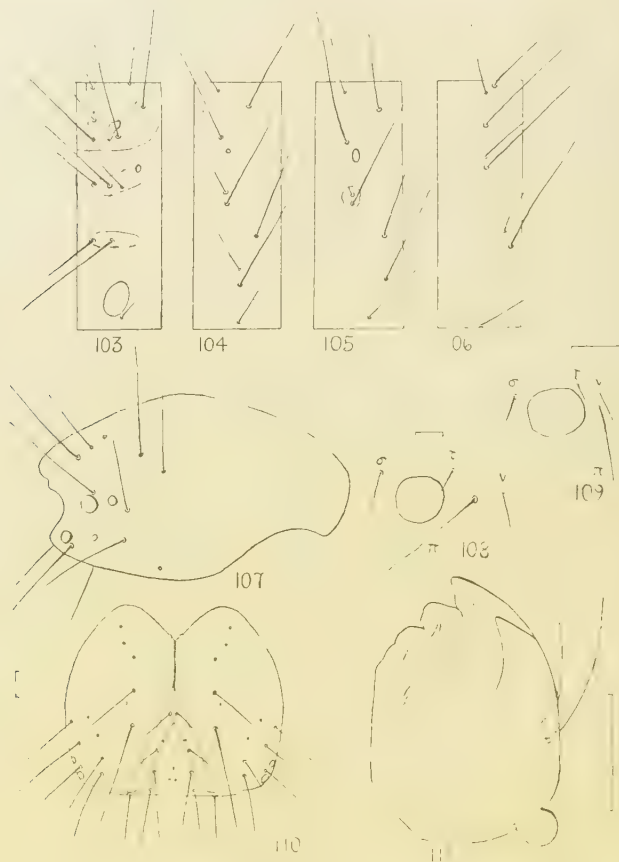
From the two other *Oecophorids* found in stored products, this may be distinguished by having six instead of four or two ocelli on each side of the head, mandible with only one instead of three large teeth, and crochets unevenly triordinal instead of biordinal.

Hofmannophila pseudospretella (Staint.)

(Figs. 103-108, 110-111, 114).

Mature Larva.—Length, 16 mm.; breadth, 3 mm. Cuticle white except as follows: head reddish-brown with anterior part of clypeus, apical part of mandibles, and sometimes an oblong meso-ventral patch opposite cardo black; setae, mouth-parts, prothoracic tergite as well as sclerite anterior to spiracle of 1, tergite of 10, peritreme of spiracles, parts of legs, and crochets moderately pale brown. *Head* with four ocelli (fig. 107), but in a few specimens first and second are not fused and there are five ocelli. Adfrontals (fig. 114) produced to a fine point caudally and extending as a narrow line in epicranial suture to, or nearly to, vertical triangle. Frontal puncture (fig. 110) only slightly nearer to frontal than to caudal clypeal seta. Labium without a pit. *Spiracles* of 8 usually distinctly oval with vertical diameter greater than horizontal, sometimes reniform with vertical diameter twice as great as horizontal, and sometimes round or nearly so; spiracles of 7 only one-third to one-half as large as those of 8 and round or oval; spiracles of 1-6 similar to those of 7; spiracles of 1 less than twice as large as those of 1 and feebly oval to reniform. *Legs* without a gibbosity on ventral (or inner) side of front trochanters. Prolegs with crochets biordinal. *Chaetotaxy* as shown in figs. 103-108, 110. Pi group of 1 bisetose, 2-6 trisetose, 7 bisetose, and 8-9 unisetose. Pi group of 3-6 with nu dorsal (or lateral) to pi.

Earlier Instars.—First and second (?) instars differ from more mature larvae in having uniordinal instead of biordinal crochets as well as having fewer crochets on each proleg. The adfrontals do not extend posteriorly beyond about caudal two-fifths of head, and the adfrontal area is not delimited laterally by a distinct suture.



Figs. 103-111.—(103) Prothorax of *Hofmannophila pseudospretella* (Staint.). (104) Seventh abdominal segment of same. (105) Eighth abdominal segment of same. (106) Ninth of same. (107) Left side of head of same. (108) Pi group of third abdominal segment of same. (109) Same of *Endrosis sarcitrella* (L.). (110) Head of *H. pseudospretella*. (111) Ventro-mesal view of left mandible of same.

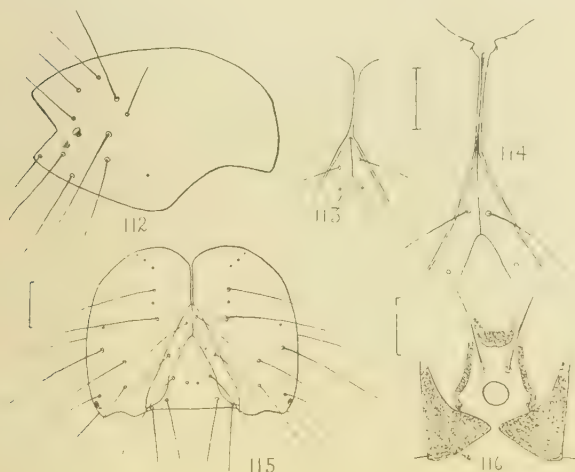
Lepesme (1938) has described the differences between the adults of *Hofmannophila* and *Borkhausenia*. Although he has used *B. stipella* (L.) (a congener of the genotype of *Borkhausenia*, *B. minutella* L.) for his comparison with *H. pseudospretella*, the differences he describes are sufficient for the removal of *pseudospretella* from *Borkhausenia*. The larva of *B. stipella* has been briefly described by Benander (1937), and a comparison of this larva with that of *H. pseudospretella* supports the conclusion, arrived at by a study of the adults, that the two species belong in different genera. The larva of *Borkhausenia* differs from that of *Hofmannophila* in having six instead of

four ocelli and in having the adfrontals fully developed and extending on a broad front to the vertical triangle instead of being reduced caudally (fig. 110).

The larva of *Hofmannophila* is evidently less specialised than that of *Endrosis*, and, as regards both the reduction of the ocelli and adfrontals, is an annectant link between most of the OECOPHORINAE and *Endrosis*.

Endrosis sarcitrella (L.)

(Figs. 109, 112-113, 115-116).



Figs. 112-116.—(112) Left side of head of *Endrosis sarcitrella* (L.). (113) Enlarged view of caudal region of adfrontals and coronal suture of same. (114) Same of *Hofmannophila pseudospretella* (L.). (115) Head of *E. sarcitrella*. (116) Labium of same to show postmental pit.

Mature Larva.—Length, 10-11 mm.; breadth, 1.5-2.0 mm. Externally nearly identical to *H. pseudospretella* in colour. The principal structural differences between the two species are as indicated in the key.

Earlier Instars.—No first instar larvae are available, but the second (?) instar differs from the more mature larvae in having the rim of the labial pit only indistinctly sclerotised. It is probable that in the first instar the crochets will be uniordinal and fewer in number.

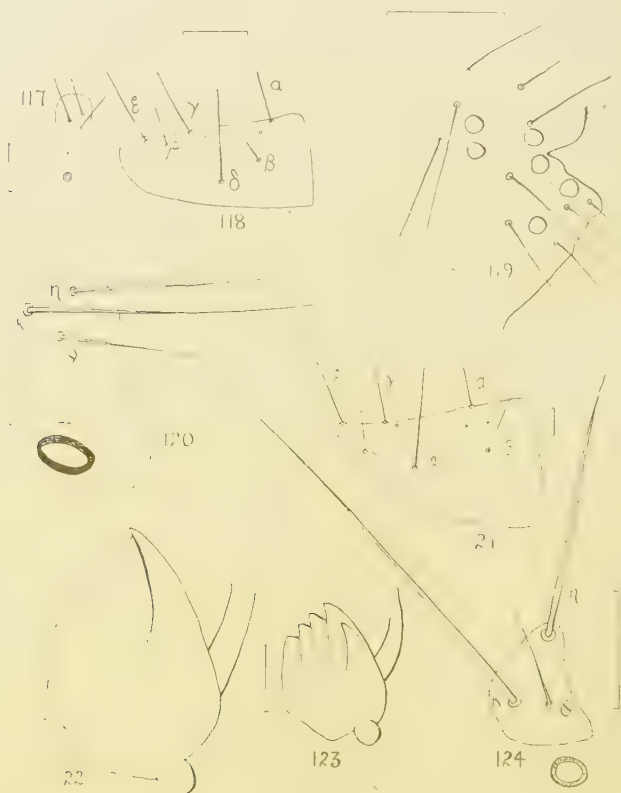
Fracker (1915) places the larva of *Endrosis* in the family BLASTOBASIDAE rather than in the OECOPHORIDAE because according to him seta rho of 8 is caudo-dorsal to the spiracle and the crochets are uniordinal instead of biordinal. In point of fact, however, seta rho of 8 (and also of 1-7) is antero-dorsal to the spiracle and the crochets are distinctly biordinal except in the first and second (?) instars. In Fracker's (1915) key *Endrosis* traces to the family STENOIMIDAE, as the adfrontals and a considerable distance from the vertical triangle, but the fact that it traces to this family is due only to a defect in his key. Benander (1937) places *Endrosis* in the BLASTOBASINAE, and his characterisation of the larvae of this group is based entirely on *Endrosis sarcitrella* (L.), the larvae of typical genera of the BLASTOBASINAE being unknown to him. However, a comparison of the larva of *Endrosis sarcitrella* with such typical OECOPHORINAE as *Harpella forficella*, Scop., *Alabonia bractella* (L.) and *Dasyneura*

sulphurella, F., shows clearly that *Endrosis* should remain in the OECOPHORINAE. The larva of *Dasycera sulphurella* possesses on the basal part of the labium a deep, heavily sclerotised pit which would appear to be homologous to the peculiar labial pit of *Endrosis*. This larva is also similar to *Endrosis* in possessing a prominent gibbosity on the inner side of the front trochanter. Furthermore, all those who have based their conclusions on a study of adult structures agree in placing *Endrosis* in the OECOPHORINAE.

The larva of *Endrosis* may be distinguished from all other known OECOPHORIDAE by having only two instead of four or six ocelli and the adfrontals much shortened caudally so that there is a long epicranial suture.

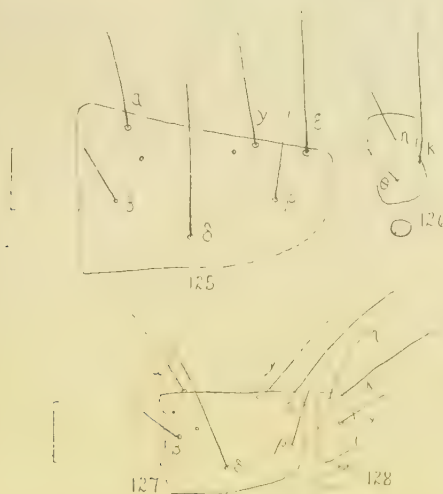
TINEIDAE.

The members of this family have not been described in detail, but an attempt has been made to include the chief distinguishing features of each species in the key. In addition to the seven species included in the key, *Tinea parasitella*, Hbn., and



Figs. 117-124.—(117) Kappa group of prothorax of *Tinea granella* (L.). (118) Prothorax of same. (119) Ocellar region of same. (120) Kappa group of prothorax of *Lindera tessellatella*, Blanch. (121) Prothorax of same. (122) Ventro-mesal view of left mandible of same. (123) Same of *Tinea ditella*, Pierce & Metcalfe. (124) Kappa group of prothorax of same.

Scardia bolleti, F., have been examined, and from a study of all of these it appears that the family characters are as follows: Head with adfrontals extending to or nearly to the vertical triangle, and front extending one-third to three-fourths of the distance to the vertical triangle. Ocelli vary in number from one to six or are altogether absent (*Tineola*), but when six are present, the first and second are in a vertical line and are considerably caudad to the third and fourth, which are also in a vertical line, an arrangement typical also of the family AGERIIDAE. Epipharynx with three large, subapical spines on each side. Mandibles each with one to five apical teeth. Maxillary mala with three large, ventro mesal spines. Spiracles round or oval with the vertical diameter greater than the horizontal and usually moderately large and conspicuous. Thoracic legs well developed; Prolegs present on 3-6 and 10, and each of four anterior pairs with a complete circle of uniordinal crochets. Anal fork absent. Chaetotaxy as follows: Kappa group of prothorax trisetose; alpha setae on 1-8 further apart than beta setae except in *Scardia*; and kappa and eta of 1-8 always very widely separated and in a horizontal or a vertical line, but if in a vertical line with kappa directly caudal to spiracle; Pi and Sigma setae of 8-9 sometimes much reduced or absent.



Figs. 125-128.—(125) Prothorax of *Tinea pallescentella* Staint. (126) Kappa group of prothorax of same. (127) Prothorax of *Tinea pellionella* (L.). (128) Kappa group of prothorax of same.

The trisetose Kappa group of the prothorax combined with the very widely separated kappa and eta of the first eight abdominal segments will serve to distinguish the members of this family from those of all others dealt with in this paper. The two chief family characters mentioned by Fracker (1915), i.e. setae alpha nearer together than beta on abdomen and the close approximation of the Kappa setae of the prothorax, are characters confined to a few genera.

It is clear from a study of the larvae that the genus *Tinea* contains many unrelated species, a fact borne out by a study of the genitalia of the adult males. If the few species which have been studied were divided into genera on the basis of larval characters, *T. pallescentella* and *T. pellionella* could probably be included in the same genus, but the three remaining species would be in three different genera.

Acknowledgments.

My best thanks are due to my colleagues, Dr. A. Steven Corbet and Mr. W. H. T. Tams, for providing me with the correct names of the various species of moths and with notes on the distribution of these species. I also have to thank Mr. H. M. Edelsten, Dr. J. A. Freeman, Mr. R. M. Greenslade, Mr. J. M. Holborn, Mr. G. T. Jefferson, Dr. O. W. Richards, and Mr. H. L. G. Stroyan for sending me larvae which would not otherwise have been included in this paper.

References.

- BARRETT, C. G. (1904). The Lepidoptera of the British Islands, **9**.
- BENANDER, P. (1937). Die Gelechiiden-Raupen. Eine vergleichendmorphologische Untersuchung.—Opuscula Ent., **2**, pp. 49–109, 37 figs.
- BRUES, C. T. & MELANDER, A. L. (1932). Classification of insects. A key to the known families of insects and other terrestrial arthropods.—Bull. Mus. comp. Zool. Harvard, **73**, 672 pp., 1,121 figs.
- BUCKLER, W. (1901). The larvae of the British butterflies and moths, **9**.
- BUSCK, A. (1917). The pink bollworm, *Pectinophora gossypiella*.—J. agric. Res., **9**, pp. 343–370, 6 pls., 7 figs.
- CORBET, A. S. & TAMS, W. H. T. (1943). Keys for the identification of the Lepidoptera infesting stored products.—Proc. zool. Soc. London, (B) **113**, pp. 55–148, 5 pls., 287 figs.
- FORBES, W. T. M. (1910). A structural study of some caterpillars.—Ann. ent. Soc. Amer., **3**, pp. 94–143, 143 figs.
- . (1923). The Lepidoptera of New York and neighbouring States.—Mem. Cornell Univ. agric. Exp. Sta., **68**, 729 pp., 439 figs.
- FRACKER, S. B. (1915). The classification of Lepidopterous larvae.—Ill. biol. Monogr., **2**, 169 pp., 112 figs.
- GERASIMOV, A. (1937). Bestimmungstabelle der Familien von Schmetterlingsraupen (Lep.).—Stettin. ent. Ztg., **98**, pp. 281–300, 18 figs.
- HEINRICH, C. (1916). On the taxonomic value of some larval characters in the Lepidoptera.—Proc. ent. Soc. Wash., **18**, pp. 154–164, 5 figs.
- . (1920). A new genus and species of Oecophorid moths from Japan.—Proc. ent. Soc. Wash., **2**, pp. 43–50, 14 figs.
- . (1921). Some Lepidoptera likely to be confused with the pink bollworm.—J. agric. Res., **20**, pp. 807–836, 17 pls.
- HOFMANN, E. (1875). Die Kleinschmetterlingsraupen. (In) S. v. Praun's Microlepidoptera. Nürnberg.
- LEPESME, P. (1938). *Hofmannophila pseudospretella* Stt. (Lep. Gelechiidae), hôte indésirable des habitations et des magasins.—Bull. Soc. ent. France, **42** (193.), pp. 283–288, 1 pl.
- MEYRICK, E. (1928). A revised handbook of British Lepidoptera.
- REINHARD, H. J. (1937). Sorghum webworm studies in Texas.—J. econ. Ent., **30**, pp. 869–872.
- RILEY, C. V. (1882). The sorghum web-worm.—Rep. U. S. Comm. Agric., **1881**, pp. 187–189, 1 pl.

A BROWN APHIS, *APHIS (DORALIS) COGNATELLA*, SP. N., FOUND ON SPINDLE TREE.

By MARGARET G. JONES.

Department of Zoology, Cambridge.

Introduction.

The spindle tree, *Euonymus europaeus*, has been recognised for some time as the chief winter host of the polyphagous *Aphis (Doralis) fabae*, Scop. Early writers described this black aphid as a distinct species under the name of *Aphis euonymi*, F., not always realising its polyphagous habits during the summer months. Recently the presence of a second, monophagous species has been recorded in Great Britain from *Euonymus europaeus* and *E. hamiltonianus*. This species is brown in colour and is very closely allied to *A. fabae*.

Walker (1850), while describing a black *Aphis euonymi*, F., on *E. europaeus*, also mentioned several brown varieties of the black type. The *A. euonymi* figured and described by Buckton (1879) was chestnut brown in colour, but the description was very incomplete and mixed with one of the black species. Continental writers (Franssen, Börner) made no mention of any brown species on spindle. Börner & Janisch (1922) did, however, separate from *A. fabae* a short-haired black *Aphis euonymi*, F., found in Central Europe.

Aphis (Doralis) cognatella, sp. n.

Colonies of this Aphid on species of *Euonymus* (*europaeus* group) can be distinguished from those of *A. fabae* by the chocolate brown colouration of the body of all adult forms: the nymphs are somewhat lighter brown. Single individuals can be distinguished by the length of the hairs, which is greater than that of similar hairs on *A. fabae*. These hairs are most easily measured on the antennae, legs, and margins of the abdomen (fig. 2, Q, T, U, fig. 3, R, S). Apart from these characters, the apterae and alatae of these closely related species are morphologically very similar. The life-histories are, however, distinct. *A. cognatella* is non-migratory, and is found on spindle tree all the year round. It has apterous sexuparae, which produce males, oviparae and viviparae. The oviparae do not possess the shortened, swollen hind tibiae so well marked in *A. fabae* (fig. 4, D, E). More detailed differences in structure are described under the separate headings.

Description and Comparison of the different Forms.

In order to save repetition, the apterae viviparae are described in detail, and the other forms only where they differ from these or from *A. fabae*. A table comparing the measurements of *A. fabae* and *A. cognatella* is given under each heading.

Fundatrices (fig. 1).

The fundatrix is about $2\frac{1}{4}$ mm. long and has a short, five-jointed antenna (fig. 1, P). There are often papillae on abdominal segments 2-6.

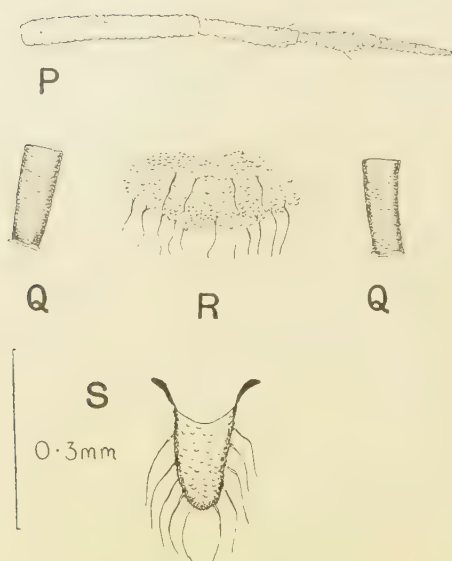


Fig. 1. Fundatrix of *A. cognatella*.—P, antenna ; Q, cornicle ; R, genital plate ; S, cauda.

TABLE I.

Comparison of the Fundatrices.

Character	<i>A. fabae</i>	<i>A. cognatella</i>
Length of hind tibia	0.860 mm.	0.813 mm.
S.E. $\pm$	0.0085 mm.	0.0079 mm.
Length of cornicles	0.197 mm.	0.200 mm.
S.E. $\pm$	0.0024 mm.	0.0022 mm.
Length of antennal joints 3 and 4	0.379 mm.	0.363 mm.
S.E. $\pm$	0.0030 mm.	0.0032 mm.
Length of antennal joints 5 and 6	0.168 mm. : 0.248 mm.	0.152 mm. : 0.235 mm.
S.E. $\pm$	0.0018 mm. : 0.0024 mm.	0.0019 mm. : 0.0034 mm.
Dorsal body pattern	Faint or absent	Faint or absent
Length of hairs on antennal joints 3 and 4	19.0 μ	36.34 μ
S.E. $\pm$	0.505 μ	0.653 μ
Length of marginal hairs	26.18 μ	51.8 μ
S.E. $\pm$	0.781 μ	0.805 μ
Number measured	53	55

Apterae Viviparae (fig. 2).

The colour of the apterous viviparous female varies from light to dark brown, and the length is about 2 mm. The head is darkly chitinated, as are the first two joints of the antenna, the distal part of the fifth, and the whole of the sixth (fig. 2). Sometimes the distal third of the fourth joint is darker brown than the proximal two-thirds. The rostrum is dark with the exception of the proximal two-thirds of the first joint, and reaches to the second, or to between the second and third coxae. There are dark bands on the pro- and meso-thoracic terga and sterna. The coxa, trochanter, distal third of the tibia and tarsus of all legs are dark; so also are the femora of the second and third pairs of legs. There is no well defined

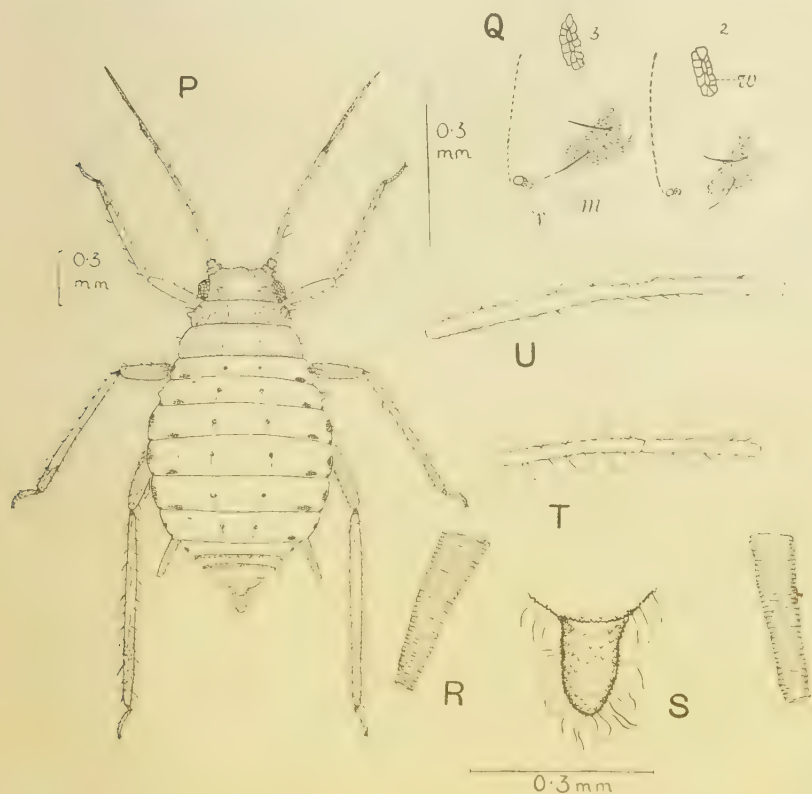


Fig. 2. Aptera, P-T of *A. cognatella*, U of *A. fabae*. P, dorsal view; Q, margin of abdominal segments 2 and 3; R, cornicles; S, cauda; T and U, 3rd and 4th joints of antenna; m, marginal hair; r, spiracle; w, wax gland.

dorsal and marginal pattern on the abdomen, although there are often dark areas at the bases of the dorsal and marginal hairs (fig. 2, Q). Posteriorly, there are dark bands on the terga of the seventh and eighth abdominal segments. The genital and anal plates, and also the cauda and cornicles are strongly chitinated (fig. 2, R, S). There are frequently white wax bands on the terga of segments 1-5, and all the dorsal and

ventral wax glands are well marked (fig. 2, P, Q). Papillae are present on the prothorax and on the abdominal segments 1 and 7 but rarely elsewhere. In *A. fabae*, papillae are more often found on abdominal segments 2-6. The hairs on the body and appendages are long (Table II) (fig. 2, Q, T) and are arranged on the body as follows: a dorsal row runs along the body on each side of the mid-line, a transverse ventral row is present in each segment (fig. 3, Q) and a small group on the margins of the thorax and abdomen. On the marginal areas of abdominal segments 1-6 the number of hairs is 1, 1-3, 2, 2, 1, 1. The lateral spiracles are clearly visible in mounted specimens.

TABLE II.

Comparison of the Apterae Viviparae on Euonymus sp.

Character	<i>A. fabae</i> *(spring forms)	<i>A. cognatella</i>
Length of hind tibia	1.173 mm.	1.014 mm.
S.E. $\pm$	0.0144 mm.	0.013 mm.
Length of cornicles	0.322 mm.	0.248 mm.
S.E. $\pm$	0.005 mm.	0.005 mm.
Length of antennal joints 3 and 4	0.400 mm. : 0.284 mm.	0.318 mm. : 0.221 mm.
S.E. $\pm$	0.006 mm. : 0.009 mm.	0.005 mm. : 0.004 mm.
Length of antennal joints 5 and 6	0.274 mm. : 0.488 mm.	0.206 mm. : 0.460 mm.
S.E. $\pm$	0.004 mm. : 0.005 mm.	0.003 mm. : 0.005 mm.
Dorsal body pattern	Faint or absent Wax bands on abdomen	Faint or absent Wax bands on abdomen
Length of the hairs on antennal joints 3 and 4	24.93 μ	54.95 μ
S.E. $\pm$	0.3996 μ	0.597 μ
Length of marginal hairs	42.4 μ	72.31 μ
S.E. $\pm$	1.03 μ	0.588 μ
Number measured... ..	53	72

*NOTE.—Apterae viviparae of *A. fabae* occur on *Euonymus europaeus* mainly in the spring, while those of *A. cognatella* are found there in summer and autumn also. Apterae of the "*fabae*" group of Aphids tend to be larger in the spring than later in the year.

Alatae Viviparae (fig. 3).

The alate viviparous females are strongly chitinated (fig. 3, P, Q). The antennae are dark and there are dark bands on the three thoracic segments and a definite dorsal and marginal pattern on the abdomen (fig. 3, P). Sensoria are present on the third (and sometimes 4th) antennal joints (fig. 3, R). Mounted specimens agree very closely with those of *A. fabae*, even the number of hooks attaching the hind to the fore wings is usually three in both species.

TABLE III.—Comparison of the *Alatae Viviparae*.

Character	<i>A. fabae</i> (spring forms)	<i>A. cognatella</i> (spring and summer forms)
Length of hind tibia	1.188 mm.	1.247 mm.
S.E. $\pm$	0.01 mm.	0.018 mm.
Length of cornicles	0.239 mm.	0.249 mm.
S.E. $\pm$	0.003 mm.	0.004 mm.
Length of antennal joints 3 and 4 S.E. $\pm$	0.365 mm. : 0.279 mm. 0.003 mm. : 0.003 mm.	0.365 mm. : 0.27 mm. 0.004 mm. : 0.004 mm.
Length of antennal joints 5 and 6 S.E. $\pm$	0.246 mm. : 0.486 mm. 0.003 mm. : 0.003 mm.	0.245 mm. : 0.505 mm. 0.005 mm. : 0.004 mm.
Number of sensoria on antennal joint 3... ..	17	17
S.E. $\pm$	0.31	0.29
Number of sensoria on antennal joint 4... ..	0.38	2
S.E. $\pm$	0.086	0.22
Dorsal body pattern	Present	Present
Marginal pattern on abdomen	Present — well marked semicircle at base of cor- nicle	Present — well marked semicircle at base of cor- nicle
Length of antennal hairs on joints 3 and 4	26.11 μ	53.92 μ
S.E. $\pm$	0.44 μ	0.54 μ
Length of marginal hairs... ..	51.04 μ	76 μ
S.E. $\pm$	0.854 μ	0.617 μ
Number measured... ..	51	65

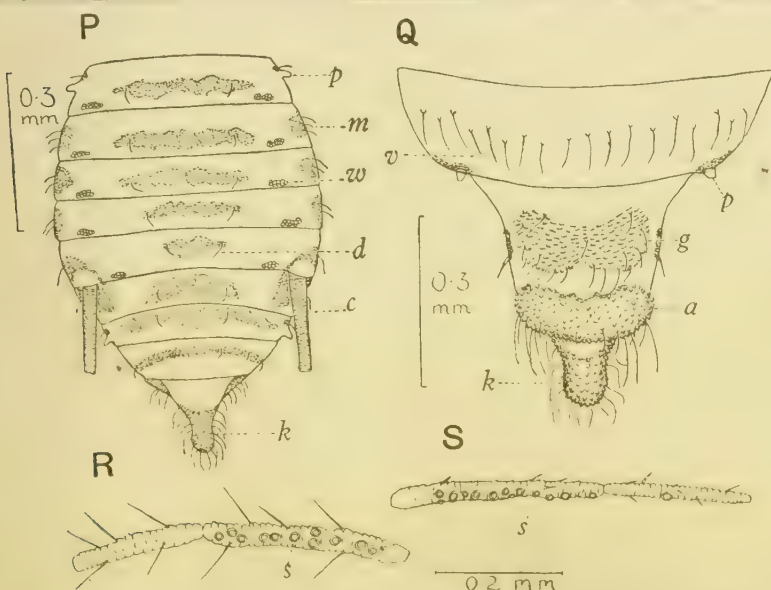


Fig. 3. *Alata vivipara*, P-R of *A. cognatella*, S of *A. fabae*. P, dorsal view of abdomen; Q, ventral view of extended posterior end of abdomen; R and S, 3rd and 4th joints of antenna. a, anal plate; c, cornicle; d, dorsal hair; g, genital plate; k, cauda; m, marginal hair; p, papilla; s, sensoria; v, ventral hair; w, wax gland.

Sexuparae.

The sexuparae are apterous and are somewhat smaller than the apterous viviparous females. A few alatae viviparae, with several sensoria on the fourth, and even on the fifth joint of the antenna, were recorded in September, but there was no evidence that they were sexuparae. The gynoparous sexuparae of *A. fabae* are alate.

TABLE IV.

*Measurements of the Alate Gynopara of A. fabae and the Apterous Sexupara of A. cognatella.**

Character					<i>A. fabae</i>	<i>A. cognatella</i>
Form	...	...	...	...	Alate	Apterous
Length of hind tibia	...	...	...	...	1.17 mm.	0.981 mm.
S.E. $\pm$	...	...	...	...	0.011 mm.	0.017 mm.
Length of cornicles	...	...	...	...	0.222 mm.	0.208 mm.
S.E. $\pm$	...	...	...	...	0.003 mm.	0.005 mm.
Length of antennal joints 3 and 4	...	...	...	...	0.369 mm. : 0.264 mm.	0.283 mm. : 0.187 mm.
S.E. $\pm$	...	...	...	...	0.003 mm. : 0.002 mm.	0.005 mm. : 0.004 mm.
Length of antennal joints 5 and 6	...	...	...	...	0.238 mm. : 0.51 mm.	0.187 mm. : 0.448 mm.
S.E. $\pm$	...	...	...	...	0.002 mm. : 0.003 mm.	0.005 mm. : 0.005 mm.
Sensoria on antennal joint 3	...	...	...	...	21	None
S.E. $\pm$	...	...	...	...	0.294	
Sensoria on antennal joint 4	...	...	...	...	5	None
S.E. $\pm$	...	...	...	...	0.203	
Sensoria on antennal joint 5	...	...	...	...	0.27	None
S.E. $\pm$	...	...	...	...	0.049	
Length of antennal hairs	...	...	...	...	27.67 μ	56.16 μ
S.E. $\pm$	...	...	...	...	0.413 μ	1.2 μ
Length of marginal hairs	...	...	...	...	54.73 μ	73.35 μ
S.E. $\pm$	...	...	...	...	1.029 μ	1.36 μ
Number measured	...	...	...	...	62	24

* The alate gynopara *A. fabae* is not strictly comparable with the apterous sexupara of *A. cognatella*, but the data are useful and are included for this reason.

Oviparae (fig. 4).

The oviparae are slightly smaller than the apterae, but the body is often elongated behind the cornicles (fig. 4, C) owing to the presence of unlaid eggs. The antenna has six joints, although occasionally the third and fourth joints are incompletely divided from one another. There are often no dorsal bands on abdominal segments 7 and 8, and the genital plate is bifid (fig. 4, F). The hind tibia bears a variable number of pseudo-sensoria and, although slightly variable in thickness, they are never as swollen as are those of *A. fabae* (fig. 4, E, D). As many as eight eggs can be seen in the body of one female.

Males (fig. 4, G).

The males are alate, with a strongly chitinated head, thorax and abdomen. The dorsal bands and marginal areas are present as in the alatae viviparae. Sensoria are present on the third, fourth and fifth antennal joints (fig. 4, G). Posteriorly, the male copulatory organs are distinct, a median aedeagus with two parameres. Unfortunately, many of the specimens measured were bred under muslin cages, and therefore may have been rather small.

TABLE V.—Comparison of the Oviparae.

Character	<i>A. fabae</i>	<i>A. cognatella</i>
Hind tibia	Swollen and shortened	Not or very little swollen
Length of hind tibia	0.577 mm.	0.766 mm.
S.E. $\pm$	0.008 mm.	0.009 mm.
Pseudosensoria on hind tibia ...	>100	8-60
Length of cornicles	0.124 mm.	0.163 mm.
S.E. $\pm$	0.001 mm.	0.002 mm.
Antenna	5-6 jointed	6-jointed, rarely 5-jointed
Length of antennal joints 3 and 4	0.169 mm. : 0.126 mm.	0.219 mm. : 0.145 mm.
S.E.	0.003 mm. : 0.002 mm.	0.0024 mm. : 0.003 mm.
Length of antennal joints 5 and 6	0.142 mm. : 0.298 mm.	0.159 mm. : 0.361 mm.
S.E. $\pm$	0.002 mm. : 0.003 mm.	0.002 mm. : 0.0031 mm.
Length of antennal joints 3 and 4 undivided	0.269 mm.	None measured
S.E. $\pm$	0.004 mm.	
Dorsal body marking	None	None on abdomen, bands on pro- and meso-notum
Length of antennal hairs on joints 3 and 4	19.63 μ	49.03 μ
S.E. $\pm$	0.495 μ	0.832 μ
Length of marginal hairs	35.08 μ	68.48 μ
S.E. $\pm$	1.356 μ	0.828 μ
Number measured... ..	59	66

0.5 mm

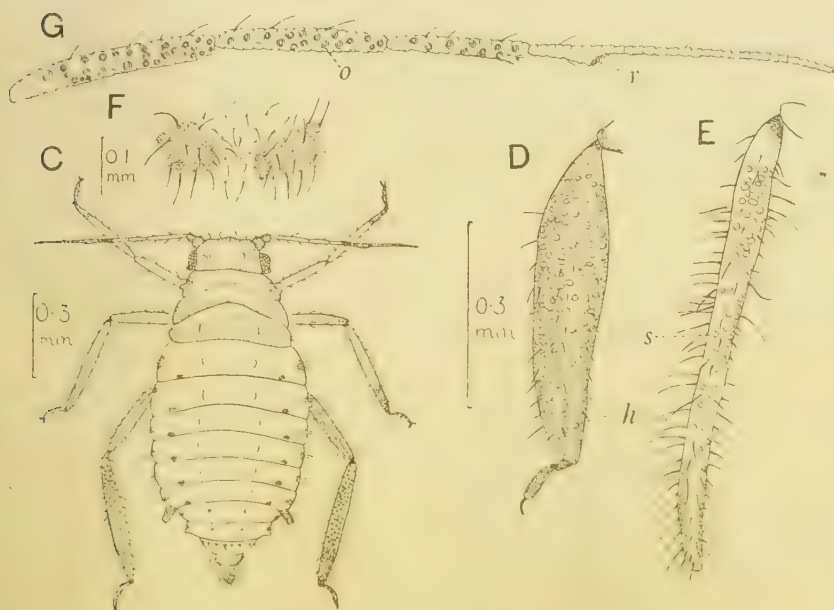


FIG. 4. Ovipara and male, C, E, F, G of *A. cognatella*, D of *A. fabae*. C, dorsal view of ovipara; D and E, hind tibia of ovipara; F, genital plate; G, antenna of male. h, hair; o, sensoria; s, pseudo-sensoria; r, rhinarium (primary sensorium).

TABLE VI.
Comparison of the Males.

Character	<i>A. fabae</i>	<i>A. cognatella</i>
Length of hind tibia	0.955 mm.	0.924 mm.
S.E. $\pm$	0.009 mm.	0.01 mm.
Length of cornicles	0.122 mm.	0.12 mm.
S.E. $\pm$	0.002 mm.	0.002 mm.
Length of antennal joints 3 and 4	0.353 mm. : 0.272 mm.	0.32 mm. : 0.233 mm.
S.E. $\pm$	0.003 mm. : 0.003 mm.	0.003 mm. : 0.002 mm.
Length of antennal joints 5 and 6	0.228 mm. : 0.477 mm.	0.204 mm. : 0.461 mm.
S.E. $\pm$	0.002 mm. : 0.004 mm.	0.002 mm. : 0.003 mm.
Number of sensoria on antennal joint 3... ..	38	36
S.E. $\pm$	0.522	0.561
Number of sensoria on antennal joint 4... ..	23	20
S.E. $\pm$	0.461	0.393
Number of sensoria on antennal joint 5... ..	12	11
S.E. $\pm$	0.347	0.275
Dorsal body pattern	Strong	Generally strong
Length of antennal hairs on joints 3 and 4	24.77 μ	32.6 μ
S.E. $\pm$	0.351 μ	0.444 μ
Length of marginal hairs... ..	41.8 μ	51.07 μ
S.E. $\pm$	0.654 μ	0.47 μ
Length of hairs on the fore tibia	29.3 μ	41.8 μ
S.E. $\pm$	0.502 μ	0.667 μ
Number measured... ..	58	45

Eggs.

The eggs are orange yellow when first laid, but soon change to a shining black, very similar in appearance to the eggs of *A. fabae*. They differ chiefly in their positions on the twig of *Euonymus* sp., being scattered at random on the internodes and nodes and not congregated chiefly in the axils of the buds as are those of *A. fabae*. When the eggs are crushed, a yellow-orange fluid is extruded, which differs from the green fluid produced by the eggs of *A. fabae*.

TABLE VII.
Comparison of the Eggs.

	<i>A. fabae</i>	<i>A. cognatella</i>
Length	0.551 mm.	0.545 mm.
S.E. $\pm$	0.004 mm.	0.003 mm.
Breadth	0.245 mm.	0.26 mm.
S.E. $\pm$	0.002 mm.	0.003 mm.

Nymphs of the Apterous and Alate Females.

There are four instars before the adult stage is reached and in all stages the hairs are long.

The first instar is about 0.83 mm. long and is pale greyish-brown in colour. The antenna is four jointed and the cornicles are small. Two dorsal rows of hairs running along the body are visible. The antennae and legs are pale.

The second instar is about $1\frac{1}{4}$ mm. long and the body is darker brown than the first. The antenna is five jointed, with darkened first, second and fifth joints. The distal third of the tibia is dark and also the tarsus. The cornicles and cauda are small.

The third instar of the apterous viviparous female is about $1\frac{1}{2}$ mm. long, and is deeper brown in colour than the second. The antenna is six-jointed, joints 5 and 6 being dark in colour. The cornicles and cauda have increased in length.

By the fourth instar, the length has increased to about $1\frac{3}{8}$ mm., and the appearance is more like that of an adult, but the cauda is still small.

The third and fourth instars of the alate female show the developing wing buds on the meso- and meta- thoracic segments. The fourth instar has white mealy bands on the abdomen and all the joints of the antenna, except part of the third, are dark brown.

Intermediates.

Two Aphids were found which were intermediate in character between an apterous viviparous female and an oviparous female. The number of sensoria on the hind tibia was low (0-2) and both winter eggs and larvae were present in the body. The viviparous larvae were situated at the proximal end of the ovarioles. It was not possible to decide whether the larvae were sexual forms. If they were, the specimens were intermediate between sexuparae apterae and oviparae, and this conclusion appears to be the most likely. This type of intermediate occurs only rarely amongst Aphids, and was produced experimentally by Shull (1930) in *Macrosiphum solanifolii*.

Biology.

A. cognatella has been recorded from parts of East Anglia, and has also been found in North Wales by Mr. F. H. Jacob. Probably its distribution is much wider.

The eggs hatch out in the middle of March or later, according to the weather, and the young, light-brown nymphs are found in the opening buds of spindle, on both surfaces of the leaves. The species appears to be less hardy than *A. fabae*, for a severe frost in 1941 killed nearly all the nymphs and fundatrices, while *A. fabae*, although depleted in numbers, was still quite common. It was also found impossible to rear individuals on spindle twigs in the laboratory, whereas *A. fabae* lived and reproduced quite readily.

The fundatrices, found chiefly on the lower surfaces of the leaves, take about three weeks to mature, and give rise to apterous viviparous females, although a few alatae may be produced. Subsequent generations produce more alatae, and this type is especially numerous in June, when migration to new host bushes takes place. The production of alatae then falls off a little, but there may be another peak production later in the year. Alatae viviparae have been recorded in September, but as they were mounted, it is not known if they produce oviparae as do the gynoparae of *A. fabae*. They were, however, similar in structure, having more sensoria on the antennal joints 4 and 5, than the summer forms. Apterous viviparae are found all through the summer. They migrate by walking from one part of a bush to another.

A. cognatella had only been found on *Euonymus europaeus* and *E. hamiltonianus* in nature until recently when one colony was found on *Viburnum opulus* in Monmouthshire. Colonies have been obtained on other host plants experimentally. Table VIII gives the results of some transference experiments, where a single aptera vivipara or alata vivipara was placed on the leaf of a small potted plant and then enclosed in a muslin sleeve; the progeny, if any, were recorded every few days. Colonies survived best on *Chenopodium album*, *Rumex obtusifolius*, *Arctium lappa*, and *Capsella bursa-pastoris*, but young were never produced on *Vicia faba*. Similar experiments with *A. fabae* always produced large and flourishing colonies on *Vicia faba*, *Papaver rhoeas*, *Cirsium arvensis*, *Beta vulgaris*, as well as on all the above plants.

TABLE VIII.

Results of Transference Experiments of single Individuals placed on some of the Summer •
Host Plants of *A. fabae*. (Parent plant=*Euonymus europaeus*.)

Trial host plant	Number of trials	Number producing one generation of young	Number producing two or more generations
<i>Vicia faba</i>	14	0	0
<i>Chenopodium album</i> ...	14	2	1
<i>Papaver rhoeas</i>	12	3	0
<i>Rumex obtusifolius</i> ...	6	5	4
<i>Arctium lappa</i>	6	3	3
<i>Cirsium arvensis</i>	7	0	0
<i>Beta vulgaris</i> (crop) ...	9	0	0
<i>Beta vulgaris</i> (seed) ...	2	1	0
<i>Capsella bursa-pastoris</i> ...	5	2	2

Outdoor transference experiments under less artificial conditions were also attempted. Nine plots were set up, in each of which a central bush of *Euonymus europaeus* was surrounded by a number of summer host plants, placed 1½–2 feet away, and the whole plot was enclosed by a muslin cage, 3 feet high (Jones, 1942). A few fundatrices or second generation apterae were placed on the central spindle bush in each plot, and any colonisation of the summer host plants by the progeny of the colony so produced was recorded. In practice, it was found very difficult to obtain flourishing colonies on the central plants, and when the original colony increased in size, most of the individuals remained on the central spindle bush. Table IX gives the number of colonies that started on the summer host plants, but none of these colonies was strong. They only consisted of a few individuals.

When a similar series of experiments was carried out with *A. fabae*, all the plants were readily colonised by both alatae and apterae (Jones, 1942).

Under the restricted conditions of an insectary, migrating apterae from three heavily infested bushes of *E. europaeus* founded colonies on neighbouring potted plants of *Rumex obtusifolius*, *R. crispus*, *Chenopodium album*, *Capsella bursa-pastoris*, *Beta vulgaris* (seed plant) and *Galeopsis speciosa*, but did not settle on *Vicia faba* or *Cirsium arvensis*.

TABLE IX.

The Results of the Cage Transference Experiments
(Number of cages=9)

Plant	Number of plants	Number of plants infested by <i>A. cognatella</i>
<i>Vicia faba</i>	9	0
<i>Beta vulgaris</i> (seed)	4	1
<i>Beta vulgaris</i> (root-crop)	5	0
<i>Chenopodium album</i>	9	2
<i>Rumex obtusifolius</i>	9	4
<i>Papaver rhoeas</i>	9	2
<i>Cirsium arvensis</i>	8	0
<i>Euonymus europaeus</i> (very small)	5	2
<i>Capsella bursa-pastoris</i>	4	0

While examining a mass of spindle bushes along the margins of a bean field, it was noted that the bushes were heavily infested with new colonies of *A. cognatella*, but a careful inspection of the beans failed to reveal a single Aphid.

From these experiments and observations, it can be seen that the feeding habits of *A. cognatella* and *A. fabae* are markedly different.

As alatae naturally settle on *Euonymus europaeus* to found new colonies, it was thought that they might show some olfactory response to the odour of spindle leaves. This possible response was tested out in a v-shaped olfactometer (Thorpe & Jones, 1937; Thorpe, 1938) using a current of air which had been drawn through *E. europaeus* leaves in a bottle on one side and through an empty but identical bottle on the other. The results gave no evidence of any olfactory response (Table X).

TABLE X.

The Response of *A. cognatella* to the Odour of Spindle Leaves.

Total No. of alatae	No. of trials	Number counted on side of spindle leaves	Number counted on side of empty bottle	S.E.	χ^2	P
581	5	286 (49.2%)	295 (50.8%)	2.62%	7.004	0.2-0.1

S.E. = $\frac{pq}{n}$ when $p = 0.5$ and $q = 1 - 0.5$, n = total number of Aphids. The value of χ^2 gives a satisfactory measure of the homogeneity of the readings.

Alate males appear in colonies of *A. cognatella* in September and also considerable numbers of oviparous females. After copulation, the oviparae lay their eggs, usually 6-8, on the bark or on the buds of primary (and sometimes secondary and tertiary)

twigs. They migrate actively while laying the eggs. Breeding experiments (Table XI) show that both males and oviparae are produced by the same apterous sexupara. To obtain these readings, single apterae were placed on spindle twigs in culture solution and each twig was enclosed in a muslin sleeve.

TABLE XI.
The Progeny of Apterous Sexuparae.

Number of mothers	Number of apterae produced	Number of alatae produced	Number of males produced	Number of oviparae produced	Number of nymphs produced	Total number of progeny
18	7	1	13	65	17	103

Acknowledgments.

I wish to thank Mr. F. G. W. Jones of the School of Agriculture, Cambridge, who first realised the presence of two distinct species of aphid on spindle tree, for suggesting the problem to me and for reading through the proofs. I am also indebted to Mr. F. Laing of the British Museum (Natural History) for the suggestion of the specific name.

Summary.

1. A new species of aphid, *Aphis (Doralis) cognatella*, found on *Euonymus europaeus* is described and compared with *Aphis (Doralis) fabae*, which it closely resembles. This new aphid is brown in colour and has long hairs.

2. Two individuals, intermediate in character between oviparae and sexuparae, are mentioned.

3. Transference experiments, carried out under somewhat artificial conditions, show that although the aphid is normally found on *Euonymus* sp., it can exist for some time on *Rumex obtusifolius*, *R. crispus*, *Chenopodium album*, *Capsella bursa-pastoris*, *Arctium lappa*, and *Beta vulgaris* (flower stalks), which are also host plants of *A. fabae*, but it does not colonise *Vicia faba*.

4. The sexuparae are apterous and produce males, oviparae and apterae, thus differing from *A. fabae*, in which there are two sexuparous forms, one an alate gynopara and the other an apterous form found on the summer hosts.

5. Olfactometer experiments give no indication of any olfactory response to the odour of *E. europaeus* leaves.

References.

- BÖRNER, C. & JANISCH, R. (1922). NachrBl. dtsh. PflSchDienst, **2**, p. 65.
 BUCKTON, G. B. (1879). Monograph of British Aphides, **2**, p. 72.
 JONES, M. G. (1942). Bull. ent. Res., **33**, p. 161.
 SHULL, A. F. (1930). Z. induct. Abstamm.- u. VererbLehre, **57**, p. 92.
 THORPE, W. H. (1938). Proc. roy. Soc., (B) **126**, p. 370.
 - & JONES, F. G. W. (1937). Proc. roy. Soc., (B) **124**, p. 56.
 WALKER, F. (1850). Ann. Mag. nat. Hist., (5) **2**, p. 278.

OVICIDAL PROPERTIES OF CERTAIN INSECTICIDES OF PLANT ORIGIN. (NICOTINE, PYRETHRINS, DERRIS PRODUCTS.)

By C. POTTER & F. TATTERSFIELD.

*Department of Insecticides and Fungicides, Rothamsted Experimental Station,
Harpenden, Herts.*

INTRODUCTION.

It has frequently been assumed that the value of insecticides derived from plants lies in their great toxicity to the active stages of the insect, nymph, larva or adult. With the exception of nicotine, which has long been recognised to possess egg-killing properties, it seems to have been generally considered that insecticides derived from plants were poor ovicides. These opinions are reflected in the literature. There are a considerable number of references to the ovicidal action of nicotine, but there appear to be very few to the ovicidal action of the pyrethrins or the derris products.

Although nicotine has been recorded as being toxic to the eggs of a considerable number of species of insects, very little quantitative work has been done. Shaw & Steer (1939), in addition to giving quantitative figures for its effect on a number of species of overwintering eggs, also discuss its mode of ovicidal action and give some of the most important references. Smith (1940) gives some quantitative data on the effect of nicotine and other nitrogenous bases on the eggs of *Lygaeus kalmii*, Stål. A complete bibliography up to 1936 is provided by McIndoo, Roark & Busbey (1936).

Although we have not made a search of the literature which has any claim to completeness, it seems that neither the pyrethrins nor the derris products have been used in practice with the express purpose of killing insect eggs, but always to control the active stages. Feytaud (1917) records that pyrethrum has some toxicity to eggs of *Polychrosis botrana*, Schiff. Onoe & Fukuda (1939) record that a solution of 0.009 per cent. pyrethrin content in 0.5 per cent. soap solution killed all the eggs of *Chik simplex*, Butl., and more detailed figures of the toxicity of the pyrethrins to this species of egg are given by Mori (1940). Nel & Mathew (1940) record the toxicity of pyrethrum to the eggs of *Ephestia elutella*, Hb., but the pyrethrins were carried in a heavy or a light petroleum oil and it is difficult to assess precisely the effect of these carriers on their toxicity. Naudé (1940) also records the toxicity of pyrethrum in heavy petroleum oil to the eggs of *Ephestia elutella*, Hb.

Turner (1932), using cubé extract in oil, found with eggs of *Dialeurodes citri*, *Grapholitha molesta* and *Paratetranychus pilosus* that there was little increase in the toxicity of the oil on adding cubé. There was an indication of toxicity of the cubé to eggs of *Pteronidea ribesii*. Haug & Peterson (1938) record that derris had some toxicity to the eggs of *Hippodamia convergens*, Guér.

Breakey & Miller (1935) report the toxicity to eggs of *Sitotroga cerealella*, Ol., of nicotine, nicotine sulphate, pyrethrum and a derris product and to eggs of *Phormia regina*, Mg., of nicotine, nicotine sulphate and pyrethrum. Maercks (1935) records the toxicity of nicotine and pyrethrum to the eggs of *Carposapsa pomonella*, L., and *Polychrosis botrana*, Schiff. Jancke & Maercks (1936) state that proprietary nicotine,

rotenone and pyrethrum sprays gave encouraging results against the eggs of plum sawflies. Okazaki (1940) state that nicotine sulphate, derris and pyrethrum were toxic to the eggs of *Agromyza oryzella*, Matsumura. From these records it may be judged that besides nicotine, the pyrethrins and the derris products might prove useful in practice as ovicides.

Having for some time been interested in the quantitative assessment of the toxicity of the active principles of derris and pyrethrum to a number of species of insects in their active stages, we considered that it was advisable to explore their ovicidal properties. A quantitative investigation was therefore started in this laboratory in 1940.

In many of the trials synthetic insecticides of recognised ovicidal value were included to serve as standards of comparison.

The experiments are detailed under the insect used as test subject.

EXPERIMENTAL.

Apparatus and Technique.

For all the experiments, except those on *Aphis rhamni*, the apparatus and general technique used was that described by one of us (Potter, 1941), the only modification of the technique was that in the majority of the experiments the eggs were placed on circles of black Italian cloth 3 cm. in diameter for treatment, instead of using white tricoline, the normal procedure for adult insects. The small circles of black cloth facilitated inspection. A dipping technique was adopted in the test on *Aphis rhamni*; this is described in the text on these experiments.

Pieris brassicae, L.

The eggs were found in considerable numbers on cabbage plants during August, 1940. A circle of leaf was cut out round each batch of eggs and these were then sprayed. Since the eggs were collected in the field they could not be standardised in any way, but some estimate of the age of the eggs could be made from their colour, and it was arranged that for any given treatment the three replicates used should consist of a batch of young, medium age and old eggs. The experiment was primarily intended as a test of the ovicidal action of rotenone; for which two solvents, dichloroethyl ether and acetone, were used; and the pyrethrins, which were first dissolved in a heavy petroleum oil and then applied as an emulsion in water, except in one instance in which they were applied in alcohol dispersion. Nicotine and lauryl thiocyanate were incorporated in the series to give additional information and for purposes of comparison. Unfortunately the test with lauryl thiocyanate was not very satisfactory as the dispersion in the 0.25 per cent. solution of sulphonated loral was not very good. It was without effect at the concentration tested.

The data obtained in these experiments are set out in Table I (a) and (b).

An inspection of Table I shows that rotenone at concentrations of 0.01 per cent. and above gave a high mortality. There is no discernible increase in mortality resulting from the use of dichloroethyl ether as a solvent in place of acetone. The two solvents by themselves showed no toxicity at the concentrations used in the experiments. Rotenone at a 0.5 per cent. concentration dissolved in acetone and suspended in sulphonated loral presented some difficulties owing to crystallisation.

The pyrethrins at 0.005 per cent. w/v in white oil emulsion gave a high mortality. Although tests with the medium alone showed no toxicity, it is highly probable that it had an effect in accentuating the toxic action of the pyrethrins. This is indicated by the figures in Table 1 (b) where the addition of a 0.4 per cent. v/v of heavy oil to an alcohol dispersion of 0.005 per cent. w/v of pyrethrins in sulphonated lorol raised the toxicity from 60 per cent. to 100 per cent. A complete kill was obtained by the pyrethrins without oil at 0.01 per cent. pyrethrins w/v . Nicotine proved completely toxic at 0.05 per cent. w/v which was the lowest concentration used.

From these experiments it is clear that rotenone and the pyrethrins can kill the eggs of *Pieris brassicae* at relatively low concentrations when applied as sprays. An investigation of the ovicidal properties of these poisons when applied in the form of dusts is needed.

Ephestia kühniella, Zell.

The Mediterranean flour moth, *Ephestia kühniella*, was next chosen as the subject for a series of experiments because (a) it was readily available, (b) the eggs may easily

TABLE I.

Toxicity of Rotenone, Nicotine, the Pyrethrins and two organic Thiocyanates to the Eggs of *Pieris brassicae*.

Description of experiment	Concs. of toxic substances mg./100 c.c.	Total eggs used	Percent. killed
Unsprayed control	—	179	0
Control 0.25% v/v sulphonated lorol	—	199	3.0
Control 2% v/v dichloroethyl ether	—	149	2.7
Control 1% v/v dichloroethyl ether	—	236	0
Control 0.2% v/v dichloroethyl ether	—	99	0
2% dichloroethyl ether and rotenone	100	57	100
2% dichloroethyl ether and rotenone	50	135	100
2% dichloroethyl ether and rotenone	10	142	94.4
Nicotine (pure)	100	220	100
Nicotine (pure)	50	122	100
Lauryl thiocyanate	200	147	0
Lauryl thiocyanate	100	152	0
0.4% pyrethrum extract in heavy white petroleum oil in 0.25% sulphonated lorol	Pyr. I and Pyr. II 5.2	127	80.3
0.4% v/v heavy white petroleum oil in 0.25% sulphonated lorol	—	111	0

Date 6.viii.1940. Potter apparatus. Gap 0.5 in. Air pressure 25.6 cms. Hg.

Medium: Various media, details in table. Basic solution in all cases 0.25% w/v sulphonated lorol in water.

Temperature: 65°F. before, 70°F. after spraying. Relative humidity 60% after spraying.

Deposits mg./cm²: 6.06, 5.80, 5.85 before, 5.80, 5.63, 5.87 after spraying.

Replicates three.

Conditions of treatment: Eggs on circles of cabbage leaf put into 9 cm. petri dishes. After spraying, eggs removed from dishes and put in 2 in. $\times$ 1 in. glass tubes covered with muslin in an incubator at room temperature and at 90% relative humidity.

Insect material: Eggs collected from the field, age not known.

(b)

TABLE I—*continued*.

Description of experiment	Concs. of toxic substances mg./100 c.c.	Total eggs used	Percent. killed
Unsprayed control	—	100	0
Control acetone 10% v/v	—	66	0
Control dichloroethyl ether 1% v/v	—	168	0
Rotenone in 1% v/v dichloroethyl ether	50	184	100
Rotenone in 10% v/v acetone	50	96	100
Lauryl thiocyanate	200	105	0
Pyrethrins I and II with 5% v/v alcohol	5	145	60
Pyrethrins I and II + 5% alcohol + 0.4% v/v of heavy white petroleum oil	5	108	100
Pyrethrins I and II with 10% alcohol	10	92	100
Pyrethrins I and II + 10% alcohol + 0.8% v/v of heavy white petroleum oil	10	112	100

Date 15.viii.1940. Potter apparatus. Gap 0.75 in. Air pressure 27.6 cm. Hg.

Medium: Various media, details in table. Basic solution in all cases 0.25% w/v sulphonated loral in water.

Temperature: 68°F. Relative humidity 52%.

Deposits mg./cm²: 5.66, 5.68 before, 5.85, 5.77 after spraying.

Replicates: three.

Conditions of treatment: as in (a).

Insect material: as in (a).

be obtained in large numbers in a suitable condition for experiments, (c) the eggs could be standardised with reference to age and other conditions, (d) the incubation period of a few days allowed a number of experiments to be carried out within a reasonably short space of time.

The insecticides used in this series of experiments were:—Rotenone, Derris resin, Pyrethrum, Nicotine, Lauryl thiocyanate, β -butoxy β 'thiocyanodiethyl ether and 3:5 Dinitro-*o*-cresol.

Materials and Technique.

The food of the insects was wholemeal flour; they were reared, for the most part, in an incubator at 20°C. and approximately 60 per cent. relative humidity, but some cultures were reared at laboratory temperatures.

To obtain eggs, the moths were paired and placed in 2 × 1 in. glass tubes containing a small pad of cotton wool moistened with a solution of glucose. The top of the tube was covered with muslin held in place by a rubber band. The tubes containing the pairs were laid on their sides on black paper on a tray. Eggs were laid in the tubes, either loose or stuck to the walls, on the muslin top, or extruded through the muslin to fall on the black paper. The eggs on the muslin top could easily be removed and they formed the chief source of supply for the experiments. The eggs loose in the tubes and those on the black paper were also used. The eggs stuck to the walls of the tube were discarded since some were difficult to dislodge and in consequence there was a serious risk of damage occurring.

For most of the experiments the tubes were placed in a constant temperature room at 27°C. and approximately 60 per cent. relative humidity, but there were exceptions. The conditions of rearing and egg laying are indicated for each experiment.

The eggs to be sprayed were collected and thoroughly mixed in order to randomise the batches. They were then weighed in order to determine approximately the number available (100 eggs weigh approximately 3.3 mg.). The eggs were then set out for spraying on circles of black Italian cloth 3 cm. diameter pasted in the centre of 9 cm. diameter petri dishes, usually 20 eggs in each dish. After treatment the dishes were covered with muslin and usually put in the constant temperature room at 27°C. and approximately 60 per cent. relative humidity. The conditions after treatment are indicated in each experiment.

There were some difficulties in assessing the results of the test. Sometimes the young larvae were only half out of the egg shell and had died there. These eggs were counted as unhatched. Of the eggs that hatched the larvae appeared in some instances perfectly healthy, while in others they were affected or dead. In all cases where the larvae were completely out of the egg-shell the eggs were counted as hatched and no discrimination based on the condition of the larvae was made.

*Experiment 1 (29.xi.40).—Effect of Rotenone, 3:5 Dinitro-*o*-cresol, Cardanol*, β -butoxy β 'thiocyanodiethyl ether in kerosene, Nicotine.*

This experiment was a preliminary one to determine whether the substances under test showed any toxicity to this species of egg and to obtain some information on the lethal concentrations necessary. A concentration of 0.25 per cent. w/v sulphonated lorol was used throughout, but apart from this the medium in which the substances were applied varied from one test to the next. β -butoxy β 'thiocyanodiethyl ether was available only as a 50 per cent. solution in kerosene so that this substance was of necessity applied as an emulsion.

The results are set out in Table II (a) and they indicate that all the substances under test exert some toxic effect on the eggs of this species.

*A phenol derived from Cashew-nut Shell Oil.

TABLE II.

(a) . *Toxicity of several Contact Insecticides to the Eggs of Ephestia kühniella.*

Substance tested	Concs. mg./100 c.c. (Active principle)	No. eggs used	Per- centage killed	Percentage killed allowing for acetone control
1. Control (unsprayed)	—	20	15	—
2. Acetone 10% v/v	—	60	11.7	—
3. Rotenone in 5% v/v acetone	100	66	31.8	22.8
4. Rotenone in 2.5% v/v acetone	50	60	15.0	3.7
5. 3:5 Dinitro- <i>o</i> -cresol in 5% v/v acetone ...	100	63	96.8	96.4
6. Cardanol in 10% v/v acetone	200	60	31.7	22.7
7. β -butoxy β 'thiocyanodiethyl ether in kerosene	200	60	26.7	17.0
8. Nicotine in 0.25% saponin and 0.125% sulphonated lorol	100	60	28.3	18.8

Date 29.x.1940. Potter apparatus. Gap 0.5 in. Air pressure 27.6 cm. Hg.

Medium: Various media, details in table. Basic solution=0.25% w/v sulphonated lorol.

Temperature: 62°F. before, 62°F. after spraying. Relative humidity 54% before, 52% after spraying.

Deposits mg./cm²: 5.16, 5.48, before; 5.54, 5.61, 5.49 after spraying.

Replicates: three.

Conditions of treatment: Eggs placed on 3 cm. diam. circles of black Italian cloth in 9 cm. petri dishes, sprayed. Dishes covered with muslin and kept in a constant temperature room at 27°C. and approximately 60% relative humidity after treatment.

Insect material: Eggs 0–2 days old.

(b) TABLE II—*continued*.

Substance tested	Concs. mg./100 c.c. (Active principle)	No. eggs used	Per- centage killed	Percentage killed allowing for acetone control
1. Control acetone 20% v/v	—	60	15	—
2. Rotenone in 20% v/v acetone (rotenone shows signs of crystallising out) ...	400	60	80	76.5
3. Rotenone in 10% v/v acetone (rotenone shows signs of crystallising out) ...	200	60	68.3	62.7
4. 3:5 Dinitro- <i>o</i> -cresol in 5% v/v acetone ...	100	60	93.3	92.1
5. 3:5 Dinitro- <i>o</i> -cresol in 2.5% v/v acetone	50	49	63.3	56.8
6. Cardanol in 20% v/v acetone	2,000	62	100	100
7. Cardanol in 10% v/v acetone	1,000	60	91.7	90.2
8. β -butoxy β' thiocyanodiethyl ether in kerosene	1,000	62	85.5	82.9
9. β -butoxy β' thiocyanodiethyl ether in kerosene	500	60	68.3	62.7
10. Nicotine 95% in 10% acetone	1,000	62	100	100
11. Nicotine 95% in 5% acetone	500	59	71.2	66.1
12. Lauryl thiocyanate in 10% v/v acetone ...	1,000	54	100	100
13. Lauryl thiocyanate in 5% v/v acetone	500	61	83.6	80.7
14. Pyrethrum in white oil (15% v/v) ...	200	61	100	100
15. White oil to correspond with No. 14 ...	—	61	63.9	57.5

Nicotine, lauryl thiocyanate, pyrethrum white oil were not graphed.
Controls (unsprayed) showed mite infestation and are not given.

Date 5.xi.1940. Potter apparatus. Gap 0.5 in. Air pressure 27.6 cms. Hg.
Medium: Various media, details in table. Basic solution = 0.25% w/v sulphonated lorol.
Temperature: 63°F. before, 66°F. after spraying. Relative humidity 58% before, 62% after spraying.
Deposits mg./cm²: 5.65 before, 5.54, 5.49 after spraying.
Replicates: three.
Conditions of treatment as in (a).
Insect material: Eggs 1–2 days old.
By combining the results in Tables II (a) and (b) plotting log concentrations against probit a rough determination of the relative potencies of these compounds could be obtained: χ^2 for rotenone, 3:5 dinitro-*o*-cresol, cardanol, β -butoxy β' thiocyanodiethyl ether were respectively .019, 1.042, .630, .843 showing considerable homogeneity in the data, χ^2 compared with the regression line for rotenone were 1.581, .443, 1.36 and the relative potencies of D.N.C./Rotenone = 3.8. Rotenone/Cardanol = 2.1. Rotenone/ β -butoxy β' thiocyanodiethyl ether = 2.5.

Experiment 2 (5.xi.1940). Effect of Rotenone, 3:5 Dinitro-*o*-cresol, Cardanol, β -butoxy β' thiocyanodiethyl ether in kerosene, Lauryl thiocyanate, Pyrethrins in oil, Nicotine.

This experiment, the results of which are set out in Table II (*b*), amplified and extended those obtained in the first experiments. It was made clear that a high kill of eggs of this species could be obtained with all the substances under consideration,

the list now including lauryl thiocyanate and pyrethrins in oil. At the foot of Table II a rough estimate of the relative potencies obtained by combining the data in the two sections of the table is given for some of the substances. The regression line for nicotine had a distinctly less steep slope than those of the other compounds tested and is not included. The effect was probably due partly to its volatility. The results with pyrethrum were complicated by the presence of the oil, which alone gave slightly over 50 per cent. kill, but there is clear evidence that toxicity was increased by the pyrethrins. The combined results of experiments 1 and 2 for 3:5 Dinitro-cresol, rotenone, cardanol, β -butoxy β 'thiocyanodiethyl ether in kerosene are graphically set out in fig. 1.

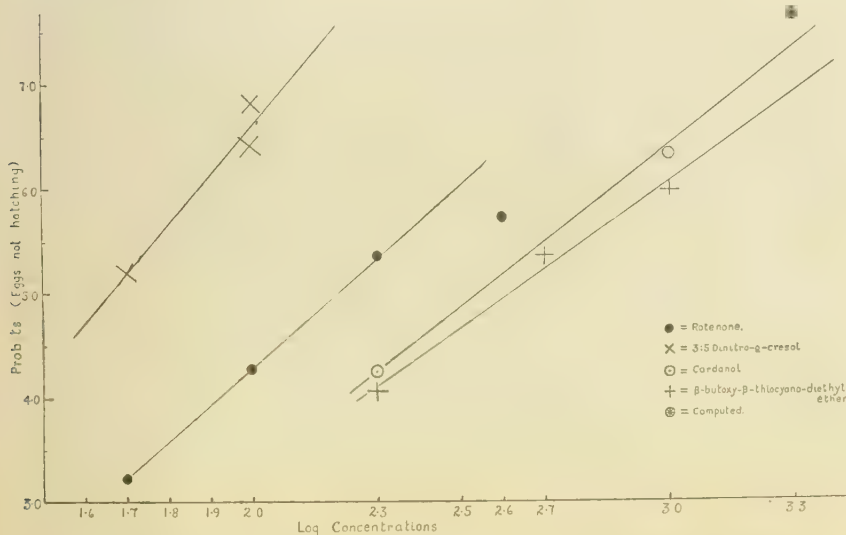


Fig. 1. Toxicity of various compounds to the eggs of *Ephestia kuehniella*, Zell. (Combined tests of 29th October and 5th November, 1940.)

After these two experiments an investigation was started on the ovicidal properties of Cashew Nut Shell Oil and its derivatives. This investigation will be reported elsewhere, but an outline of the results with lauryl thiocyanate included in some of these experiments, is given here.

The first experiment with lauryl thiocyanate showed that under similar conditions to those already described, in a medium of 10 per cent. acetone and 0.25 per cent. sulphonated lorol and with a deposit of 5.6–5.7 mg. cm², 100 per cent. kill was obtained with concentrations ranging from 0.25 per cent. 0.75 per cent. w/v. An unsprayed control gave a mortality of 12.5 per cent. and a sprayed control a mortality of 13.3 per cent. A second experiment under very similar conditions, but using a medium of 5 per cent. acetone and 0.25 per cent. sulphonated lorol and eggs aged 0–17 hours, indicated that a 50 per cent. kill was obtained at approximately 0.1 per cent. w/v of lauryl thiocyanate.

A further experiment with this compound on eggs of different ages strongly indicated that the age of the egg influenced its resistance. For future comparative experiments they were therefore standardised in this respect.

Experiment 3 (12.iii.1941).—Effect of Nicotine.

The effect of nicotine in a medium of 5 per cent. acetone and 0.25 per cent. sulphonated lorol on eggs of *E. kuehniella*, 4.5–21.5 hours old, was tested, the results

are given in Table III, together with the conditions of test. The eggs were kept after spraying in the laboratory in order to avoid attack by mites, which were present in the constant temperature room and a serious cause of trouble.

These results give an indication of the toxicity of nicotine to this species of egg, but the results at the lower concentrations are somewhat anomalous, probably owing to its volatility.

TABLE III.
Toxicity of Nicotine to Eggs of Ephestia kühniella.

Concentration % Nicotine $\frac{w}{v}$	Mortality	Percentage kill allowing for controls
0.5	39/45	85.65
0.3	23/43	49.95
0.18	12/44	21.75
0.108	15/45	28.27
0.065	17/46	32.17
Unsprayed control	2/42	—
Sprayed control	4/43	—

Date 12.iii.1941. Potter apparatus. Gap 0.5 in. Air pressure 25.6 cms. Hg.

Medium: 5% acetone in 0.25% $\frac{w}{v}$ sulphonated lorol.

Temperature: 66.5°F. before, 63.8°F. after spraying. Relative humidity 58% before, 58% after spraying.

Deposits mg./cm²: 4.8–5.0 before, 4.9–5.0 after spraying.

Replicates: Three, each with approximately 15 eggs.

Conditions of treatment: Eggs placed on 3 cm. diam. circles of black Italian cloth in 9 cm. petri dishes and sprayed. Dishes covered with muslin and kept in laboratory after treatment.

Insect material: Eggs from 4 hours old to 21 hours old. Insects reared on wholemeal flour in laboratory and in an incubator at 20°C. Eggs laid and kept before spraying in a constant temperature room at 27°C. and approximately 60% relative humidity.

Experiment 4 (27.i.1942).—Effect of Pyrethrins.

This experiment was preceded by a preliminary test in which 2 replicates each of 25 eggs were treated with concentrations of 0.4, 0.2, 0.1, 0.05 per cent. $\frac{w}{v}$ total pyrethrins. A complete kill was obtained at all these concentrations. The medium used was 20 per cent. acetone and 0.25 per cent. sulphonated lorol. The eggs were 0–18 hours old at the time of spraying and were kept after spraying in the constant temperature room at 27°C. and 60–70 per cent. relative humidity. The general conditions were similar to those in preceding experiments.

This test was followed by the experiment set out in Table IV (a) and graphed in fig. 2. This experiment provides good data on the toxicity of the pyrethrins to eggs of *Ephestia kühniella*. The results are homogeneous and cover the susceptibility range. It will be seen that the position of the regression line for this experiment differs from that of later experiments, a result probably due to a combination of a lighter deposit and younger eggs.

Experiment 5 (23.ii.1942). Effect of Pyrethrins, Rotenone, 3:5 Dinitro-o-cresol.

An attempt was made to obtain a comparative estimate of the toxicities of these three substances to the eggs of *Ephestia kühniella*. This proved a matter of some difficulty since both rotenone and 3:5 dinitro-o-cresol are crystalline and may separate and aggregate on diluting the acetone solution with the aqueous sulphonated lorol. This is particularly true of rotenone, and our data in this experiment showed

very variable results, percentage mortalities ranging between 17 and 54 per cent. for concentrations mg./100 cc. of 50–400. Thus the data obtained in its case were useless for comparative purposes. The results from the pyrethrins and dinitro-*o*-cresol are given in Table IV (b).

Omitting one badly aberrant point in the case of the pyrethrins, homogeneous and comparable data were obtained which enabled an estimate of relative potency with 3:5 dinitro-*o*-cresol to be made. For these eggs the pyrethrins were approximately 7–10 times the more toxic. This roughly agrees with figures obtained later (14.v.42), but in which homogeneous data for the dinitro-*o*-cresol suitable for comparative purposes were not obtained.

As a result of the experience gained in this experiment, it was decided to do a similar experiment, but to substitute a derris resin for the pure rotenone. This experiment is described below.

*Experiment 6 (14.v.1942).—Effect of Pyrethrins, Derris resin W.216 and 3:5 Dinitro-*o*-cresol.*

This experiment provided homogeneous data for computing the regression line of the pyrethrins, but 3:5 dinitro-*o*-cresol, probably for reasons stated above, gave results which were heterogeneous and only allowed the conclusion to be drawn that the pyrethrins have relatively a much higher insecticidal potency for these eggs, which is of the order stated in Table IV (b). The results for these substances are given in Table IV (c).

The concentrations of derris resin (37–40 per cent. of rotenone) used proved too high, 100 per cent. kill being obtained in every case for concentrations above 12.5 mg./100 cc.

The results obtained with the pyrethrins in this experiment are also shown graphically in fig. 2, together with those of experiments 4 and 7 (27.i.42 and 23.v.42).

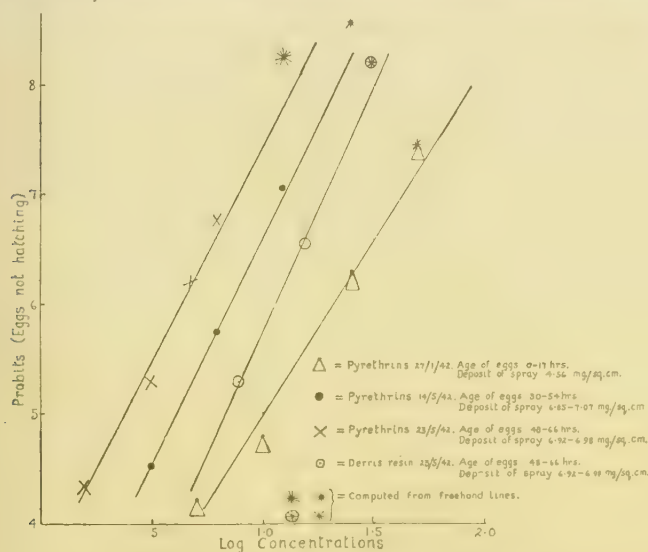


Fig. 2. Toxicity of the pyrethrins and derris resin to the eggs of *Ephestia kuehniella*, Zell.
(Combined tests of 27th January and 23rd May, 1942.)

TABLE IV.

Toxicity of Pyrethrins, Derris Resin and 3:5 Dinitro-o-cresol to Eggs of Ephestia kühniella.

No. of eggs	Concentration mg./100 c.c.	Percentage of eggs not hatching (corrected for control)	Working probit	
(a) Tests 27. i.1942. Sprayed control, 49 eggs, 57.1% did not hatch				
<i>Pyrethrins I and II</i>				
50	50	100	7.464*	Data not heterogeneous
48	25	90.5	6.311†	b=slope=3.199
51	10	42.5	4.811†	
49	5	21.8	4.221†	
(b) Tests 23. ii.1942. Sprayed control, 45 eggs, 25% mortality. Unsprayed control, 45 eggs 33.3% mortality. Mean 29.29% did not hatch				
<i>Pyrethrins I and II</i>				
49	50	100	7.134	Omitting concentration 12.5
49	25	85.6	6.061	Data not heterogeneous
51	12.5	28.0	omitted	b=slope (pyrethrins)=2.01
49	6.25	39.4	4.733	$\chi^2_D = 1.33$
49	3.125	33.8	4.608	M = 927 ± 0.75
<i>3:5 Dinitro-o-cresol</i>				
50	100	77.4	5.751	Pyrethrins are 8.45 ± 1.47 times as toxic as dinitro-o-cresol
49	50	39.4	4.733	
53	25	22.7	4.272	Data not heterogeneous
(c) Tests 14. v.1942. Sprayed control, 42 eggs, 14.3% did not hatch				
<i>Pyrethrins I and II</i>				
60	25	100	8.581*	Data not heterogeneous
60	12.5	98.0	7.060	b=slope=4.186
60	6.25	74.7	5.762	
60	3.125	31.9	4.531	
<i>3:5 Dinitro-o-cresol</i>				
60	100	100	7.094*	Data heterogeneous
58	50	47.7	4.931	
56	25	16.7	4.033	
(d) Tests 23. v.1942. Sprayed control, 106 eggs, 13.2% did not hatch (5 replicates)				
<i>Pyrethrins I and II</i>				
60	12.5	100	8.259*	Data not heterogeneous
60	6.25	96.2	6.767	b=slope=3.988
60	4.7	88.5	6.199	$\chi^2_D = .274$
57	3.125	61.6	5.289	Departure from parallelism not significant
60	1.56	25.1	4.336	
<i>Derris Resin</i> (approximately 37-40% of rotenone)				
60	31.25	100	8.213†	M=log $\frac{\text{potency of pyrethrins}}{\text{potency of derris resin}}$
59	15.6	94.1	6.565	= $.4249 \pm .0425$
60	7.8	61.6	5.295	Relative potency = 2.66 ± 0.26
<i>3:5 Dinitro-o-cresol</i>				
60	100	100	7.094†	Data not heterogeneous
60	75	96.2	6.695	b=slope=4.390
59	50	49.2	4.970	
59	25	8.2	3.684	Data heterogeneous

* Computed from freehand regression line.

† Experimental probits.

TABLE IV—*continued*.

Dates: (a) 27.i.1942. (b) 23.ii.1942. (c) 14.v.1942. (d) 23.v.1942.

Potter apparatus: Gap (a) and (b) 0.5 in., (c) and (d) $1\frac{7}{8}$ in.

Air pressure: (a) 18.4 cm. Hg. (b), (c), (d) 18.9 cms. Hg.

Medium: 0.25% w/v sulphonated lorol and 20% v/v acetone.

Temperature:

(a) 51°F. Relative humidity 55%.

(b) 57°F. before, 56°F. after spraying. Relative humidity 56% before, 55% after spraying.

(c) 63°F. before, 66°F. after spraying. Relative humidity 60% before, 58% after spraying.

(d) 62°F. before, 64°F. after spraying. Relative humidity 68% before, 60% after spraying.

Deposits mg./cm²: (a) 4.56, (b) 4.44, (c) 6.85-7.07, (d) 6.92-6.98.

Replicates: Three of approximately 20 eggs at a time.

Conditions of treatment: (a), (b), (c), (d). Eggs were placed on circles 3 cm. diam. of black Italian cloth in the centre of 9 cm. petri dishes and sprayed. After spraying the dishes were covered with muslin and placed in a constant temperature room at 27°C. and approximately 60% relative humidity.

Insect material:

(a) Insects reared on wholemeal flour in incubator at 20°C. and approximately 60% relative humidity. Pairs put in constant temperature at 27°C. and approximately 60% relative humidity for egg laying. Eggs 0-17 hours old.

(b) Insects reared on wholemeal flour in the laboratory until pupation, put in incubator at 20°C. and approximately 60% relative humidity for moth emergence. Pairs kept in incubator for egg laying. Eggs 4-22 hours old.

(c) Insects reared on wholemeal flour in laboratory or incubator at 20°C. and approximately 60% relative humidity. Pairs put in constant temperature room at 27°C. and approximately 60% relative humidity for egg laying, but eggs kept in the laboratory for approximately 30 hours before treatment. Eggs 30-54 hours old.

(d) Insects reared on wholemeal flour in laboratory or incubator at 20°C. and approximately 60% relative humidity. Pairs put in constant temperature room at 27°C. and approximately 60% relative humidity for egg laying. Eggs kept in laboratory for approximately 24 hours before treatment. Eggs 48-66 hours old.

Experiment 7 (23.v.1942).—Effect of Pyrethrins, Derris resin W.216 and 3:5 Dinitro-*o*-cresol.

The concentrations chosen for this experiment covered more closely the mortality range than those for the previous experiment, otherwise the conditions were very similar. Good data were obtained except in the case of 3:5 dinitro-*o*-cresol, which showed heterogeneity. The figures are set out in table IV (d) and shown graphically in fig. 2. It will be seen that under the conditions of the experiment using eggs of 48-66 hours old, the pyrethrins were 2.7 times as toxic as Derris resin W.216 (rotenone content=37-40 per cent.). 3:5 Dinitro-*o*-cresol was much less toxic than either.

One point of considerable interest is that the toxicity weight for weight of the Derris resin W.216 as shown in experiment (7) is considerably greater than that of pure rotenone as shown in experiments (1), (2) and (5). This is probably partly accounted for by the lower spray deposits in the case of the rotenone, especially in experiment (5), but the evidence strongly supports the view that in the resin the rotenone contained is more effective than in the pure state, probably as a result of the non-crystalline material acting as a protective colloid and preventing the rotenone from forming crystalline aggregates, which for many years now have been known not to exert their full insecticidal action.

Summing up the results of these experiments, it seems quite clear that the insecticides of vegetable origin (the pyrethrins, derris resin and nicotine) are highly toxic to the eggs of *Ephestia kuehniella* and compare favourably, weight for weight, with 3:5 dinitro-*o*-cresol, one of the most potent of the ovicides in use at the present day.

Sitotroga cerealella, Ol.

In order to extend the range of species on which the insecticides were tested, some experiments were made with eggs of *Sitotroga cerealella*, Ol., the Angoumois grain moth.

Materials and Technique.

The insects were reared on whole wheat in the constant temperature room kept at 27°C. and approximately 60 per cent. relative humidity. In order to obtain eggs, oviposition sites were prepared by fixing together with rubber bands pairs of microscope slides, separated by thin strip of index card placed at each end. The moths laid eggs freely in the artificial slit in between the two slides.

A number of these sites were put in 2 lb. glass jars and the moths confined in the jars.

After oviposition, the slides were taken out and the rubber bands removed from each pair of slides, which were then carefully separated. The eggs, which were laid in batches of varying size, were removed from the slides and placed on 3 cm. circles of Italian cloth for treatment.

Experiment 1 (5.xi.1940).—Effect of Rotenone and 3 : 5 Dinitro-*o*-cresol.

This was a preliminary experiment to test the effect of rotenone and 3 : 5 dinitro-*o*-cresol at concentrations of 50 mg./100 c.c. in a medium of 10 per cent. acetone and 0.25 per cent. sulphonated lorol in water with a deposit of approximately 5.32 mg./cm². No attempt was made to standardise the age of the eggs. The conditions were the same as in Experiment 2 (p. 230), on *Ephestia kühniella*. The results showed that these substances were without toxic effect at the above concentrations. Since the eggs of *Ephestia kühniella* show a high mortality at the same concentration of 3 : 5 dinitro-*o*-cresol, the eggs of *Sitotroga cerealella* must be more highly resistant to these insecticides.

Experiment 2 (14.v.1942).—Effect of the Pyrethrins and Derris resin W.216. (Rotenone=37–40 per cent.)

This was a more extended test to determine the effect of the pyrethrins and derris resin. The resin was used since pure rotenone crystallises out of the high concentrations that must be used with this species.

The age of the eggs was standardised in this test. The conditions of treatment were the same as in Experiment 6 (p. 233), on *Ephestia kühniella*, in fact in each treatment the eggs of *Sitotroga cerealella* were placed on one-half of the circle of black Italian cloth and the eggs of *Ephestia kühniella* on the other. The results of the experiment on *Sitotroga cerealella* are set out in Table V.

From this table it will be seen that a high mortality was obtained with both the pyrethrins and derris resin, but that the eggs are very much more resistant than those of *Ephestia kühniella*.

One interesting feature of this experiment was the long delay in hatching in the case of the eggs treated with the derris resin. This delay was six days or more beyond the controls for a high proportion of the treated eggs. This increase in the incubation period indicates that the rate of metabolism had been decreased by the derris resin and may help to elucidate its mode of toxic action.

These experiments suffice to show that the pyrethrins and derris resin are toxic to the eggs of *Sitotroga cerealella*, but that higher concentrations are needed than those required to kill eggs of *Ephestia kühniella*. The experiment with 3 : 5 dinitro-*o*-cresol indicated that their resistance was high to this ovicide as well.

Plutella maculipennis, Curt.

Two experiments were carried out with a pyrethrum extract on the eggs of this species. This insect was used primarily because it was a plant feeder. Since most of our work had so far been done using as test subjects insects attacking stored food, it was thought desirable to obtain as much additional information as possible on the

effect of insecticides on the oviposition of insects is a matter which requires further investigation. The present experiments have been preliminary in character.

Under suitable conditions for spraying had yet to be worked out. Since the number of eggs was small, only the pyrethrins could be tested, but it was most desirable to have as full information as possible about the range of their ovidical properties.

TABLE V.

Toxicity of Pyrethrins and Derris Resin to the Eggs of Sitotroga cerealella.

No. of eggs used	Concentration mg. 100 c.c.	Percentage of eggs not hatching corrected for a control of 25
Sprayed control. 36 eggs, 25% did not hatch.		
<i>Total pyrethrins</i>		
63	50	87
60	25	6.7
43	12.5	—
72	6.25	9
66	3.12	—
<i>Derris resin</i> . Rotenone content approximately 37-40%		
81	2.000	68.7
70	1.000	41
67	500	41.6
65	250	24.1
43	125	13

Date: 14.v.1942. Potter apparatus. Gap 1 cm. Air pressure 18.9 cms. Hg.

Medium: 0.25% w/v sulphated lard and 20% v/v acetone.

Temperature: 63°F. before, 66°F. after spraying. Relative humidity 60% before, 56% after spraying.

Deposits mg. cm²: 6.85 before, 7.07 after spraying.

Replicates: three of approximately 20 eggs each.

Conditions of treatment: Eggs placed on 3 cm. diam. circles of black Italian cloth in the centre of 9 cm. petri dishes and sprayed. Dishes covered with muslin and placed in a constant temperature room at 27°C. and approximately 60% relative humidity.

Insect material: Insects reared on wheat in constant temperature room at 27°C. and approximately 60% relative humidity. Pairs kept in constant temperature room for egg laying.

Days 5-25 incubation.

Material and Technique.

The insects were reared on cabbages in muslin cages in a glasshouse. Some eggs were laid on the cabbages in the cages, but for convenience of handling the insects were reared on cabbages in muslin cages. It was found, however, that if insects hatched on 2 in. pins were put in a glass container with some cabbage leaves under them for 24 hours in a constant temperature room at 27°C. and 60-70% relative humidity, they were laid comparatively readily on the pin-plant cabbages.

Various methods of preparing the eggs for spraying were tried. In the first experiment pieces of cabbage with the eggs laid on them were cut out and placed on tricoline in a 9 cm. petri dish and sprayed. A difficulty was met in finding the eggs for inspection and in examining them when the cabbages started to shrivel. In the second experiment three dishes were sprayed at each concentration and each was treated in a different way. In the first dish the eggs were taken off the cabbage and put on to circles 3 cm. diameter of black Italian cloth in the petri dish, in the second the eggs were taken off the cabbages and put on filter paper in the dish, and in the third the eggs were left on the cabbage, which was cut up and put on tricoline in the dish as in the first experiment. It was found that the first method was the most satisfactory, and this has been adopted in subsequent experiments with this species. The difference in method of treatment is not detailed in the description of the experiments, which can only be considered as qualitative.

Experiment 1 (27.i.1942).—Effect of Pyrethrins.

Three concentrations of pyrethrins were tested in a media of 20 per cent. acetone and 0.25 per cent. sulphonated lorol, on eggs of unknown age. The results are set out in Table VI.

TABLE VI.

Effect of Pyrethrins on Eggs of Plutella maculipennis.

Concentration total pyrethrins mg./100 c.c.	Mortality	Percentage kill allowing for controls
10	27/37	67.58
5	18/20	85.0
2.5	11/31	3.24
Control sprayed	9/27	

Two replicates were used for each point, dishes put into glasshouse after treatment. Other spraying conditions as in Experiment (4) *Ephestia kühniella*.

Besides giving some information on the concentrations of pyrethrins in 20 per cent. acetone and 0.25 per cent. sulphonated lorol that were toxic to these eggs, there was some indication that the resistance of the egg was affected by age. This may account for some of the anomalous variation in the results.

Experiment 2 (12.ii.1942).

This was an extended trial of the effect of pyrethrins. The results are set out in Table VII.

From this table it will be seen that the pyrethrins are toxic to the eggs of this species, which appear to be more susceptible to their effects than the eggs of *Ephestia kühniella*.

The results are not amenable to statistical treatment probably because the eggs were not sufficiently standardised with regard to age and because, as outlined above, each replicate was treated differently.

The experiments on *Plutella maculipennis* demonstrate quite clearly that the pyrethrins are toxic to the eggs of this species, and, in spite of heterogeneity in the results, indicate the range toxicity.

TABLE VII.

Toxicity of the Pyrethrins to the Eggs of Plutella maculipennis.

No. of eggs used	Concentration mg./100 c.c. total pyrethrins	Percentage of eggs not hatched (corrected for a control of 10.3%)	Remarks
Unsprayed and sprayed controls, 68		eggs, 19.2 and 10.3% respectively did not hatch	
60	20	77.7	Data too heterogeneous for purposes of computation
61	10	34.2	
67	5	26.7	
58	2.5	27.0	
70	1.25	6.0	

Date: 12.ii.1942. Potter apparatus. Gap 0.5 in. Air pressure 16.1-18.4 cm. Hg.

Medium: 0.25% w/v sulphonated loral and 20% w/v acetone.

Temperature: 64°F. Relative humidity 52%.

Deposits mg./cm²: 4.47.

Replicates: Three, each of approximately 20 eggs drawn from three different batches.

Conditions of treatment: Of the three replicates at each concentration (a), (b), (c)

(a) Consisted of young eggs about three days old removed from cabbage and placed on 3 cms. diam. circles of Italian cloth in a 9 cm. petri dish.

(b) Consisted of eggs of unknown age, left on the cabbage leaf which was placed on a circle of tricoline in a 9 cm. petri dish.

(c) Consisted of eggs of unknown age, left on the cabbage leaf which was placed on a circle of tricoline in a 9 cm. petri dish.

After spraying the dishes were covered with muslin and put in a cool glasshouse.

Insect material: Insects reared on cabbages in cages in a glasshouse of variable temperature.

Eggs laid on cabbage leaves and treated as above.

Aphis rhamni, Boyer.

The experiments so far described were all carried out on eggs hatching in a few days; in the case of the plant insects the eggs used developed normally under summer conditions. It seemed desirable to test the effect on an overwintering egg since it was thought that the different conditions of development might have an important effect on toxicity.

Materials and Technique.

Owing to the kindness of Mr. J. P. Doncaster, of the Plant Pathology Department of this station, we were able to obtain in 1942 a large number of buckthorn twigs badly infested with the eggs of *Aphis rhamni*. The twigs bearing the eggs were obtained on 28th March, 1942, and were kept in damp sand until treated. A dipping treatment was adopted for the application of the insecticides.

Preparation Procedure.

The twigs were examined, and those which had more than 30 uncollapsed eggs were selected for treatment. Each of the selected twigs was more closely examined and the collapsed eggs removed as far as possible. The eggs remaining were counted and the twig numbered. The bottom of the twig was then inserted in a piece of pressure tubing about $\frac{3}{8}$ in. long, $\frac{3}{8}$ in. external diameter and $\frac{1}{16}$ in. internal diameter so that the bottom of the twig projected about 1-1 $\frac{1}{2}$ in. This tubing was held inside

a slightly larger piece of tubing that just fitted test tubes $\frac{3}{4}$ in. in diameter. The test tubes had their bottoms cut off to leave a length of about $4\frac{1}{2}$ in. long and their tops were covered with muslin. Each twig was placed in the test tube so that it enclosed that part of the twig bearing the eggs; the bottom of the tube was stoppered up by the rubber tubing beyond which the twig projected.

As each tube was prepared it was given the twig number and was suspended through netting of a tightly fitting mesh. The netting was then suspended over a trough of water and each tube adjusted by means of a thick rubber stop band so that the bottom of the twig dipped in water. A single tube ready for insertion into the netting is illustrated in Fig. 3.

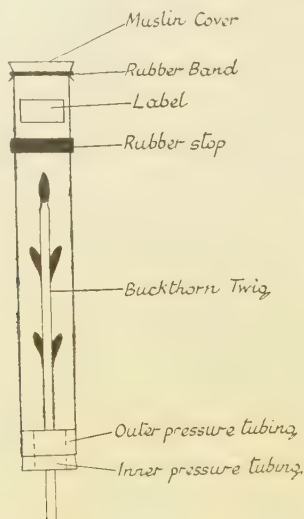


Fig. 3. Diagram showing method of keeping dipped buckthorn twigs.

By means of this procedure all insects that emerged from the dipped eggs were trapped in the tubes and could be counted. This is a very necessary procedure, since it is very difficult to make an accurate assessment by counting the eggs shells on the twigs, and the number of hatched insects is therefore more reliable.

Dipping Procedure.

The solutions were prepared in a measuring cylinder. The base of each twig was grasped by a pair of curved forceps, and it was immersed in the solution for 10 seconds by the stop watch. On removal it was shaken once to get rid of excess fluid and the pressure tubing was cleaned from fluid by means of filter paper. The twig was then replaced in its numbered tube and put back into the wire rack with the base of the twig dipping in water. Dipping was done at laboratory temperature. After the twigs had been dipped, they were removed to a cool glasshouse and kept for examination.

Examination.

Counts were made of the number of hatched insects in the tube and the unhatched eggs ascertained by deducting this figure from the number of eggs originally recorded for the twig. These data were confirmed as far as possible by examination of the

egg shells and eggs on the twigs. It was not found possible, however, to make an accurate count of the total number of eggs present on the twig and absolute accuracy is not claimed, but apart from one or two instances it appeared quite satisfactory.

*Experiment 1 (9.iv.1942).—*Effect of Pyrethrins, Derris resin, Nicotine, Cardanol and 3 : 5 Dinitro-*o*-cresol.

The results of this experiment are set out in Table VIII.

TABLE VIII.

Toxicity of Insecticides of Vegetable Origin to the Eggs of Aphis rhamni.

(10.iv.42.)

Infested twigs dipped in solutions and emulsions at several concentrations. For details of technique see text.

Name	No. of eggs	Concentrations of insecticide %	Percentage not hatching
Controls untreated...	264		48.9
Pyrethrins (total) ...	550	1.0, 0.35, 0.12, 0.04, 0.0125	None hatched
Derris resin (37–40% rotenone)	347	4.5, 1.5, 0.5, 0.15, 0.05	None hatched
Cardanol*	719	4.5 1.5, 0.5, 0.15, 0.05	None hatched No significant effect; about 50% hatched in each case (as in control)
Nicotine †	674	2.0, 1.1, 0.65, 0.35, 0.2	None hatched
3 : 5 Dinitro- <i>o</i> -cresol as a check ...	470	0.5, 0.3, 0.15, 0.1, 0.05	None hatched
Total 3,024			

* A derivative of Cashew-nut Shell Oil. A series of experiments have been carried out on the toxicity of this substance, which will be published separately.

It will be seen from this experiment that all the insecticides with the exception of cardanol gave 100 per cent. kill. The results with cardanol are listed in order to show that the eggs possess some resistance beyond that required for the control.

At first sight this is a surprising result, but the explanation very probably lies in the time the eggs were treated; this was very late and hatching had already commenced, so that, in effect, fully developed nymphs enclosed in an egg shell were being treated. If the eggs had been treated earlier it is very probable that a different result would have been obtained. It has, however, some practical value since the pyrethrins, derris and nicotine can all be applied at any time of the year, and it is obviously an advantage if the most susceptible period of the egg can be chosen for treatment.

NOTES ON THE DEVELOPMENT OF EGGS TREATED WITH THE VARIOUS OVICIDES.

Records have previously been made on the embryonic development of eggs treated with insecticides of plant origin. Many of the references given in the introduction to this paper include notes on this subject. There seems to be universal agreement that with nicotine the embryo in the egg becomes fully developed or

nearly so before it is killed, and the few references we have been able to trace to the action of pyrethrum point to a similar course of events. Various hypotheses have been put forward to account for this phenomenon, but so far there does not appear to be any experimental evidence on which a theory may be soundly based. Several authors have recorded that the susceptibility of the egg to nicotine decreases with age; Maercks (1935), Onoe & Fukuda (1939), Mori (1940) have shown that this is also true of pyrethrins. If this is generally true, it is to be noted that in our experiments eggs in an early stage of development were taken, whenever possible, and thus the most stringent tests for the ovicidal properties of these insecticides were provided.

In most of our experiments with all the insecticides derived from plants, considerable development of the embryo occurred in treated eggs which did not hatch, and this was so at all percentage kills. There were, however, some exceptions to this rule and the results were not always uniform.

The following is an account of the action of the various insecticides, from which it is to be noted, that while among them the observable effects on the treated eggs were different, for each individual substance they were apparently the same for all species.

Pyrethrins.

Effects were observed with *Pieris brassicae*, L., *Plutella maculipennis*, Curt., *Ephestia kühniella*, Zell., and *Sitotroga cerealella*, Ol. With the acetone-sulphonated lorol-water medium, normally a high proportion of the unhatched eggs had embryos that had become either fully developed or highly developed before dying. This development occurred at all percentage kills. Its amount was not constant and some eggs were killed with partially developed embryos, indicating that a toxic action was being exerted before full development had been attained. Apart from the embryos dying and shrivelling up instead of hatching, the eggs appeared quite normal and death could only be deduced when shrinkage of the embryo had occurred. In one experiment on *Ephestia kühniella* (Table II (*b*) and 14 and 15), the pyrethrins were dissolved in a heavy mineral oil and applied as an emulsion in 0.25 per cent. sulphonated lorol in water. In this case there was no development in the treated eggs where 100 per cent. kill was produced, but the oil alone gave 57.5 per cent. kill and here also no development occurred in the eggs that did not hatch. This result does not accord with a previous experiment on *Pieris brassicae* (Table I), in which the pyrethrins were applied in a similar manner in oil. The cause of the difference between the two results may lie in the amount of oil in the emulsion, since much less oil was used with *Pieris brassicae* than with *Ephestia kühniella*.

Rotenone and Derris Resin.

Observations were possible on *Pieris brassicae*, L., *Ephestia kühniella*, Zell., and *Sitotroga cerealella*, Ol. It appears that death due to these substances may occur at all stages, ranging from no sign of development to the fully developed egg. The factors influencing the stage at which the egg poisoned by these substances dies, is not clear. With the species used, treated eggs do not develop normally since they remain filled with fluid even in the final stage of the embryo. Eggs that have developed to a considerable extent, when they die, turn black, possibly due to bacterial or fungal growth, they do not dry up and collapse in the same way as untreated eggs that die.

Reference has already been made to the fact that treatment with derris products may lengthen the incubation period of the eggs (p. 236).

Nicotine.

The results are observable in *Pieris brassicae*, L., and *Ephestia kühniella*, Zell., in both species a high proportion of the treated eggs that did not hatch contained fully

developed larvae throughout the mortality range, the proportion of fully developed larvae in the unhatched eggs was probably higher than with either the pyrethrum or the derris products. Eggs seem to develop normally until the fully developed embryo died and shrivelled up instead of emerging.

Organic Thiocyanates.

Some results were obtained with *Pieris brassicae*, L., and *Ephestia kühniella*, Zell. Considerable development occurred in the eggs that had been treated with lauryl thiocyanate and did not hatch. This development of unhatched eggs occurred over the whole mortality range. Nothing unusual was observed about the eggs. The few observations made on β -butoxy β 'thiocyanodiethyl ether indicated that little development occurred in eggs killed by this substance, but it was only obtainable as a solution in light mineral oil and the presence of the oil may have had considerable effect.

3 : 5 Dinitro-o-cresol.

Results were observable on *Ephestia kühniella*, Zell., only and with this species very little development of eggs that were killed by the poison took place. Normally the eggs that were killed collapsed undeveloped and appeared similar to the non-viable eggs in the controls.

We have purposely refrained from putting forward any suggestions to account for the difference that can be observed in the action of the various poisons, but we believe that a more detailed study of the effect of these ovicides on eggs might give some valuable information on their mode of action.

ACKNOWLEDGMENT.

We wish to express our thanks to Mrs. M. Piggott for help in carrying out the spray tests.

SUMMARY.

The pyrethrins, nicotine, rotenone and a derris resin have been tested in the laboratory under standard conditions for their ovicidal effect. The test-subjects were: *Pieris brassicae*, *Plutella maculipennis*, *Aphis rhamni*, *Ephestia kühniella* and *Sitotroga cerealella*. Notes on the technique of egg production are given for these species. In the majority of the tests made a water medium containing acetone together with sulphonated lorol as a wetting agent was used.

It has been shown that all these products are toxic to the species on which they were tested. Lauryl thiocyanate, β -butoxy β 'thiocyanodiethyl ether and 3:5 dinitro-o-cresol were included as substances of recognised ovicidal value for purposes of comparison.

All the above insecticides derived from plants compared favourably in their toxic action with the synthetics. In two instances during tests on eggs of *Ephestia kühniella*, data were obtained enabling a satisfactory statistical comparison of relative potency to be made. In the first of these, the pyrethrins were found to be 8.45 ± 1.47 times as toxic as 3 : 5 dinitro-o-cresol, while in the second the pyrethrins were found to be 2.66 ± 0.26 times as toxic as a *Derris elliptica* resin (rotenone content 37-40 per cent.). It therefore appears that both the pyrethrins and the derris resin were more toxic, weight for weight, than 3 : 5 dinitro-o-cresol which is recognised as one of the most potent ovicides.

The above vegetable poisons were found to be toxic not only to eggs developing in a few days without a diapause, but also to those of *Aphis rhamni*, a species of overwintering egg. The tests on *A. rhamni* were made at the time the eggs were just starting to hatch. The same result might not have been obtained with eggs at an earlier stage of development.

Observations were made on the effect of the different insecticides on the development of the egg. This effect appeared to differ with each substance, either qualitatively or quantitatively, but within the limits of the experiment it seemed to be independent of the species of the egg.

CONCLUSIONS.

In addition to nicotine, the pyrethrins and derris products must be regarded as potential ovicides.

References.

- BREAKEY, E. P. & MILLER, A. C. (1935). Halowax as an ovicide.—J. econ. Ent., **28**, pp. 358–365.
- FEYTAUD, J. (1917). Recherches sur l'Eudémis et la Cochylis dans le Bordelais en 1914.—Ann. Serv. Épiphyt., **4**, pp. 218–265.
- HAUG, G. W. & PETERSON, A. (1938). The effect of insecticides on a beneficial Coccinellid, *Hippodamia convergens* Guer.—J. econ. Ent., **31**, pp. 87–92.
- JANCKE, O. & MAERCKS, H. (1936). Versuche zur Bekämpfung der Pflaumen-sägewespen.—Prakt. Bl. Pflanzenb., **14**, pp. 189–198.
- MCINDOO, N. E., ROARK, R. C. & BUSBEY, R. L. (1936). A bibliography of nicotine. —E-392, U.S. Dep. Agric., Bur. Ent. Plant Quar., Washington, D.C.
- MAERCKS, H. (1935). Ueber die Wirkung von Nikotin und Pyrethrum auf die Eier des Apfelwicklers (*Carpocapsa pomonella* L.) und des bekreuzten Traubenwicklers *Polychrosis botrana* Schiff.—Anz. Schädlingssk., **11**, pp. 13–19.
- MORI, H. (1940). Lethal effect of contact insecticides upon insect eggs. I. Pyrethrin.—Oyo Dobuts. Zasshi, **12**, pp. 208–214. (Rev. appl. Ent., (A) **30**, (1942), p. 17.)
- NAUDÉ, T. J. (1940). Work on the control of insect pests. Annual Report of the Division of Entomology.—Fmg. in S. Afr., **15**, no. 177, p. 514.
- NEL, R. G. & MATHEW, G. E. A. (1940). The toxic effect of pyrethrum and aliphatic thiocyanate upon the eggs and larvae of *Ephestia elutella* Hbn., and the adults of *Sitophilus oryzae*, L., and *Bruchus chinensis* T.—Ent. Mem. Dep. Agric. For. S. Afr., **2**, pt. 4, pp. 41–51.
- OKAZAKI, K. (1940). On the bionomics of *Agromyza oryzella* Matsunura, and laboratory tests on some insecticides against it.—Ōyō Kontyū, **2**, no. 4, pp. 148–161. (Rev. appl. Ent., (A) **29**, (1941), pp. 98–99.)
- ONOE, T. & FUKUDA, J. (1939). Effectiveness of pyrethrum against the eggs of *Chilo simplex* Butl.—Oyo Dobuts. Zasshi, **11**, nos. 3–4, pp. 146–147. Tokyo. (Rev. appl. Ent., (A) **27**, (1939), p. 620.)
- POTTER, C. (1941). A laboratory spraying apparatus and technique for investigating the action of contact insecticides. With some notes on suitable test insects.—Ann. appl. Biol., **28**, pp. 142–169.
- SHAW, H. & STEER, W. (1939). Studies on the toxicity of certain nitrophenols, thiocyanates, naphthalene derivatives and organic bases to the eggs of some common orchard pests.—J. Pomol., **16**, pp. 364–388.
- SMITH, C. F. (1940). Toxicity of some nitrogenous bases to eggs of *Lygacus kalmii*. —J. econ. Ent., **33**, pp. 724–727.
- TURNER, N. (1932). Notes on rotenone as an insecticide.—J. econ. Ent., **25**, pp. 1228–1237.

THE CULICINE MOSQUITOS OF SYRIA AND THE LEBANON.

By H. C. M. PARR, R.A.M.C.

2nd Malaria Field Laboratory, M.E.F.

It was decided in May 1942 to make a survey of the Culicine mosquitos of Syria and the Lebanon, but the more important work dealing with the Anophelines prevented a complete and detailed one of the whole of Syria, though that of the Lebanon is more or less complete. Where only one or two records exist for any particular species, it cannot be presumed that these mosquitos are not common, and a subsequent detailed survey would probably reveal not only a wider distribution of some species but also the presence of others not recorded here.

Whenever possible, eggs and larvae were bred out and permanent mounts made of the larval and pupal skins, and consequently identification of most of the species was based on larval, pupal and adult characters.

The identification keys used were taken from Marshall's "British Mosquitoes" 1938, and Kirkpatrick's "Mosquitoes of Egypt" 1925. It was found necessary to alter and to make new additions to these as they did not contain all those species found to be present.

I wish to thank Lieutenant-Colonel MacDonald, R.A.M.C., Malariologist, for permitting me to complete this work, Major H. S. Leeson, R.A.M.C., Entomologist, and Major O. Theodor, R.A.M.C., Entomologist, for their invaluable help in the construction of the keys and the confirmation of the species.

Uranotaenia unguiculata, Edw. A single female was found resting among the vegetation in the daytime at Ammiq swamp in November, and a single larva was taken there in October. The breeding place was a small clay pit, 6-8 inches deep and containing green algae and a certain amount of vertical vegetation. *U. unguiculata* has not been found in any other part of Syria or the Lebanon.

Theobaldia (Theobaldia) subochrea, Edw.—The adult is easily confused with *T. annulata* but is easily recognised in the larval and pupal stages. Males and females were taken at Ammiq swamp in July, this being the only occasion on which *T. subochrea* has been recorded.

Theobaldia (Theobaldia) annulata (Sch.).—Abundant in all parts of Syria and apparently at all times of the year. Buxton found this species in Palestine only during the spring months, but here larvae and adults have been found throughout September to March. It breeds in swamps, small seepage pools and rain water cisterns, and its common associates are *Culex hortensis* and *C. laticinctus*.

Theobaldia (Allothobaldia) longiareolata (Macq.).—Common in coastal towns and villages throughout the spring and autumn months and is always found in close association with man. It breeds in rock pools, marsh pools, cisterns, pits and large swamps. *T. longiareolata* was found with *Anopheles claviger*, *A. marteri* and *Culex mimeticus* in a small rocky pool at Antelias in March, and in a shallow rain water pool at Raclidyé in association with *C. hortensis*. Large numbers of adults were caught at Ammiq in September.

Taeniorhynchus (Coquillettidia) richiardii (Fic.).—Only the adult has been found at Ammiq in August, when males and females were caught in large numbers. Buxton writes, "Cropper's specimens from Lake Huleh are still in the British Museum. No subsequent collector has obtained it." No breeding of *T. richiardii* was found at

Ammiq, but it is possible that owing to the unusual habits of the larvae, they were missed when dipping was carried out in the autumn of 1942. A thorough search of the stems and roots of all aquatic vegetation is now being carried out at Ammiq at least once every fortnight, but in spite of this no breeding has been found to date.

Taeniorhynchus buxtoni, Edw.—Only the adults have been taken in small numbers at Ammiq swamp in July.

Aëdes (Stegomyia) aegypti (Linn.).—Common in towns and villages throughout the coastal zone but almost entirely absent from inland areas. The adult is common throughout the summer and winter months until December. From January to March no adults have been found in Beirut, and it is not known how this species survives the winter there. Breeding occurs in water butts, rain water cisterns, small pools and in shallow flower pots during the months June to October. Its common associates are *C. laticinctus* and *T. longiareolata*. *A. aegypti* flies in the day-time. It has been seen in small swarms on a hot August afternoon, hovering in the shade of nearby trees, and during the day as a source of great annoyance to people living in the vicinity.

Aëdes (Ochlerotatus) mariae (Sergent). A single female was caught indoors at Beirut in September. No details of breeding are available.

Culex hortensis, Fic.—Widely distributed in the spring. Buxton has no records of this mosquito from Palestine outside the months January to April inclusive. The larva has been found almost everywhere along the Syrian coast from Beirut southwards during the spring months, and contrary to Buxton was found breeding in a rain water cistern at Qoubbe on 9th September. Also males and females were caught at night at Ammiq swamp on 19th September. Breeding occurs in open, unshaded shallow pools containing dense grass vegetation, and its common associates are *T. longiareolata*, *T. annulata* and *C. laticinctus*, and on one occasion a single pupa of *A. caspius* was taken from a pool in which the larvae of *C. hortensis* occurred in large numbers.

Culex laticinctus, Edw.—This species is abundant in coastal areas during the summer months, breeding commencing in late spring. Adults were caught at Ammiq in September, at Beirut in September and at Afrine in October. The larva was found in association with *C. tritaeniorhynchus* in a water cistern at Qoubbe on 29th August.

Culex mimeticus, Noé.—Common throughout the summer months in coastal and inland areas, and breeding commences quite early in the year. It breeds in rocky rain water pools in the dried-up beds of streams and rivers. Adults of both sexes were caught at Ammiq on the night of 15–16th September. The larva was found at Antelias on 9th March, Nahr es Safa on 22nd July, and in a pool at Chebaniye on 29th September. At Nahr es Safa in September its associate was *Anopheles superpictus*, and at Antelias in March its associates were *A. marteri*, *A. claviger* and *T. longiareolata*.

Culex (Culex) molestus (Forsk.).—A domestic species whose distribution probably extends to every town and village in Syria and the Lebanon. Females have been caught in houses and barrack rooms at Beirut throughout the winter months, and at night have proved themselves a source of great annoyance to sleepers. Little is known of the habitats of this species in Syria.

Culex theileri, Theo.—Found locally and is by no means a common species. Adults were taken at Ammiq swamp on 14th July and from a tent on the Hassetché-Qamichly road on 30th September. The larva was found at Deir Aachair in August by a Polish correspondent who unfortunately omitted to send details of the breeding place.

Culex tritaeniorhynchus, Giles.—No adults have been recorded, but larvae, subsequently bred out, were found in a rain water cistern at Qoubbe during August.

Culex univittatus, Theo.—Common in all parts of the country during the summer and autumn months. Breeding occurs in swamps, pools and slow running streams containing dense aquatic vegetation.

Table to show the Association with each other of the Larvae of different Species of Syrian and Lebanon Mosquitos.

	<i>U. unguiculata</i>	<i>T. subochrea</i>	<i>T. annulata</i>	<i>T. longiareolata</i>	<i>T. richardii</i>	<i>T. buxtoni</i>	<i>A. aegypti</i>	<i>A. mariae</i>	<i>C. hortensis</i>	<i>C. laticinctus</i>	<i>C. mimeticus</i>	<i>C. molestus</i>	<i>C. theileri</i>	<i>C. tritaeniorhynchus</i>	<i>C. univittatus</i>	<i>A. marteri</i>	<i>A. claviger</i>	<i>A. superpictus</i>	<i>A. sacharovi</i>
<i>U. unguiculata</i> ...	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
<i>T. subochrea</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>T. annulata</i> ...	1	—	—	—	—	—	—	—	—	2	—	2	—	—	—	—	—	—	1
<i>T. longiareolata</i> ...	—	—	—	—	—	—	—	—	2	2	1	1	—	—	—	1	1	—	—
<i>T. richardii</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>T. buxtoni</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>A. aegypti</i> ...	—	—	—	—	—	—	(2)	—	—	—	—	1	—	—	—	—	2	—	—
<i>A. mariae</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>C. hortensis</i> ...	—	—	—	2	—	—	—	—	(2)	2	—	1	—	—	—	—	—	—	—
<i>C. laticinctus</i> ...	1	—	2	2	—	—	—	—	2	(2)	1	3	—	—	—	—	1	1	2
<i>C. mimeticus</i> ...	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	1	1	—
<i>C. molestus</i> ...	—	—	2	1	—	—	1	—	1	3	—	(1)	—	—	—	—	1	—	1
<i>C. theileri</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>C. tritaeniorhynchus</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—
<i>C. univittatus</i> ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>A. marteri</i> ...	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—
<i>A. claviger</i> ...	—	—	—	1	—	—	2	—	—	1	1	1	—	1	—	1	—	1	—
<i>A. superpictus</i> ...	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	1	—	1
<i>A. sacharovi</i> ...	1	—	1	—	—	—	—	—	—	2	—	1	—	—	—	—	—	1	—

The figures in parentheses denote the number of times that each species occurred alone.

The figures not in parentheses denote the number of times that any two species occurred together.

Table to show the seasonal Distribution of the Culicine Mosquitos of Syria and the Lebanon.

	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<i>U. unguiculata</i>					A	L					
<i>T. subochrea</i>	A										
<i>T. annulata</i>	A	A	A	A	LA	LA					
<i>T. longiareolata</i>				A	LA	LA			L	LA	LA
<i>T. richiardii</i>	A		A								
<i>T. buxtoni</i>	A										
<i>A. aegypti</i>	A	A	A	LA	LA	A					
<i>A. mariae</i>				A	A					LA	LA
<i>C. hortensis</i>			LA	LA		L			LA	LA	LA
<i>C. laticinctus</i>			LA	LA	LA	A	A			LA	LA
<i>C. mimeticus</i>				LA	LA				L	LA	LA
<i>C. molestus</i>	A		A	LA	LA	LA	A	A	A	A	LA
<i>C. theileri</i>	A		A							L	
<i>C. tritaeniorhynchus</i>			LA	A	A					L	
<i>C. univittatus</i>					A	LA					

L=larvae.

A=adults.

KEY TO THE ADULT CULICINE MOSQUITOS OF SYRIA AND THE LEBANON.

- Sixth longitudinal vein ending before the base of the 2nd longitudinal vein.....
Uranotaenia unguiculata
Sixth longitudinal vein ending beyond the base of the 2nd longitudinal vein.....2
- Pulvilli absent. (*Theobaldia* ; *Taeniorhynchus* ; *Aedes*).....3
Pulvilli present ; eyes almost touching. (*Culex*).....9
- Spiracular bristles present. (*Theobaldia*).....4
Spiracular bristles absent. (*Taeniorhynchus* ; *Aedes*).....6
- Mesonotum with well defined white lines ; femora and tibiae striped and spotted ; male palpi shorter than the proboscis..... *Theobaldia longiareolata*
Mesonotum uniformly dark.....5
- Wing spots distinct ; scales on abdomen white.....*Theobaldia annulata*
Wing spots less distinct ; scales on the abdomen ochreous.....
Theobaldia subochrea
- Post-spiracular bristles absent ; cerci not exserted. (*Taeniorhynchus*).....7
Post-spiracular bristles present ; cerci long and exserted. (*Aedes*).....8
- Large speckled species ; wing scales dark and pale ; tarsi banded.....
Taeniorhynchus richiardii
Large species but not so speckled ; wing scales all dark ; tarsi not banded
Taeniorhynchus buxtoni

8. Thorax with silver lyre pattern ; tarsi ringed with silver scales.....*Aedes aegypti*
Thorax uniformly brown ; 5th hind tarsus entirely pale.....*Aedes mariae*
9. Wings spotted along the costa.....*Culex mimeticus*
Wings not spotted.....10
10. Abdominal pale bands basal or reduced to lateral patches.....11
Abdominal pale bands apical.....*Culex hortensis*
11. Abdominal pale bands produced backward in the centre to form a triangle ;
femora and tibiae striped.....*Culex theileri*
Abdomen not so ; femora and tibiae not striped.....12
12. Abdominal bands white.....13
Abdominal bands ochreous.....*Culex molestus*
13. Abdominal bands less than half the width of the segment.....14
Abdominal bands at least half the width of the segment.....*Culex laticinctus*
14. Hind tibia with pale lateral stripe.....*Culex univittatus*
No lateral stripe on hind tibia.....*Culex tritaeniorhynchus*

KEY TO THE CULICINE LARVAE OF SYRIA AND THE LEBANON.

1. Distal end of the siphon modified and bearing teeth. (*Taeniorhynchus*).....5
No teeth on the distal end of the siphon.....2
2. Siphon with one pair of ventral tufts.....3
Siphon with several tufts. (*Culex*).....9
3. Siphonal tuft at the base. (*Theobaldia*).....7
Siphonal tuft near the middle.....4
4. A large siphonal plate on each side of abdominal segment VIII at the apex of
which is a comb of spines in a single row.....*Uranotaenia unguiculata*
No chitinous plate on abdominal segment VIII, a patch of scales only.....6
5. Pentad hairs with fewer than 4 branches.....*Taeniorhynchus richiardi*
Pentad hairs with more than 4 branches.....*Taeniorhynchus buxtoni*
6. Small scales on abdominal segment VIII arranged in a triangle ; antennae with a
small tuft of several hairs.....*Aedes mariae*
Small scales on abdominal segment VIII arranged in a single row ; antennae
short and with a single small hair on the shaft.....*Aedes aegypti*
7. Siphon with 6-10 widely spaced pecten teeth.....*Theobaldia longiareolata*
Pecten teeth on siphon more compact and with their tips drawn out into long
hairs.....8
8. The distance between the post-clypeal hairs equal to or greater than the distance
between the inner post-antennal hairs.....*Theobaldia annulata*
The distance between the post-clypeal hairs less than the distance between
the inner post-antennal hairs.....*Theobaldia subochrea*
9. Comb of abdominal segment VIII with 4-8 large sharp teeth.....
Culex univittatus
Comb of abdominal segment VIII with numerous small scales in a triangular
patch.....10
10. Siphonal tufts in a single row.....11
Siphonal tufts more or less paired.....12

11. First 2 or 3 tufts between the pecten teeth.....*Culex laticinctus*
None of the tufts between the pecten teeth.....*Culex theileri*
12. Siphonal tufts rather numerous, some much longer than the diameter of the siphon 13
Siphonal tufts fewer ; none longer than the diameter of the siphon.....14
13. Antennae pale except on the portion beyond the sub-apical bristles ; sub-apical bristles only a little more than half way along the portion of the shaft beyond the antennal tuft.....*Culex mimeticus*
Antennae entirely or at least more than half dark ; sub-apical bristles quite near the tip.....*Culex hortensis*
14. Siphon 6-7 times as long as the breadth at the base.....*Culex tritaeniorhynchus*
Siphon 4-5 times as long as the breadth at the base ; pecten with rather long denticles.....*Culex molestus*

KEY TO THE CULICINE PUPAE OF SYRIA AND THE LEBANON.

1. Trumpet modified, pointed and bearing backwardly directed barbs. (*Taeniorhynchus*) 5
Trumpet not modified and not bearing barbs.....2
2. Trumpet short and with no transverse folds near the base.....3
Trumpet long and with numerous folds near the base.....4
3. Paddle as long as or nearly as long as broad.....6
Paddle longer than broad.....8
4. Paddle with the apex angular and serrated.....*Uranotaenia unguiculata*
Paddle with the apex rounded.....9
5. Abdominal segment 1 with a conspicuous tuft of hairs.....*Taeniorhynchus buxtoni*
Abdominal segment 1 with no tuft of hairs.....*Taeniorhynchus richiardii*
6. Trumpet short and almost as wide as long.....*Theobaldia longiareolata*
Trumpet 2-3 times as long as broad.....7
7. Denticles on paddle pointed.....*Theobaldia subochrea*
Denticles on paddle blunt.....*Theobaldia annulata*
8. Lateral setae A of abdominal segment VIII composed of a tuft of 4-5 long strong hairs.....*Aedes aegypti*
Lateral setae A of abdominal segment VIII composed of a tuft of 7-8 short weak hairs.....*Aedes mariae*
9. Lateral setae A of abdominal segments III to VI, usually single.....
Culex mimeticus
Lateral setae of abdominal segments III to VI with 2-6 branches.....10
10. Trumpet short and broad at the apex.....11
Trumpet long and narrow at the apex.....12
11. Trumpet 3 times as long as broad.....*Culex laticinctus*
Trumpet 4 times as long as broad.....*Culex univittatus*
12. Lateral setae C of abdominal segment IV with 4-6 branches.....13
Lateral setae C of abdominal segment IV with 7-10 branches.....14

13. Trumpet quite parallel sided.....*Culex molestus*
 Trumpet slightly broadening towards the apex.....*Culex hortensis*
14. Large species ; lateral setae B of abdominal segment IV with 3-4 branches.....
Culex theileri
 Small species ; lateral setae B of abdominal segment IV with 4-6 branches.....
Culex tritaeniorhynchus

The form of *Culex pipiens* that occurs in Syria, I have called *Culex pipiens molestus*, but it is understood that in order to prove that this is distinct from the typical form, it is necessary to ascertain whether or not the female will produce fertile eggs without a blood meal, and at the time of writing experiments are being carried out to achieve this object.

Although only fifteen species of Culicines are recorded here, it is certain that others exist in certain parts of Syria. It is probable that only seven species occur in the Lebanon, and that these are those already mentioned. Two species of *Aedes* have been recorded, but I am sure that others exist in the coastal area. I have examined two Levantine species of *Aedes*, one which was possibly *A. geniculatus* or *A. echinus*, and the other *A. detritus*, but both specimens were in such a bad state of preservation that an accurate identification was impossible. Owing to the fact that circumstances did not permit a complete survey of the whole of Syria, the seven species of *Culex* given here do not represent the mosquito fauna of that country. The Bekka Plain has hardly been touched—there being only a few records from Ammiq swamp—and I regard this area as being an entomologist's paradise, providing unlimited scope to the ardent insect collector. Owing to the unique geographical and climatic factors that prevail in the Bekka, an extensive survey of this valley would probably reveal the presence of Culicine species that do not occur in other parts of Syria.

REARING LOCUSTS IN CAPTIVITY.

By MARIA T. VOLKONSKY.

While assisting my late husband, Dr. M. A. Volkonsky, in his work on locusts at Algiers, I accumulated considerable practical experience with regard to the technique of mass breeding of locusts in cages, as well as making some observations on their behaviour. The following notes do not pretend to be scientific, but they may be of interest and value to other workers.

Anacridium aegyptium, L.

This species is common in the orchards, on high trees, brambles and among reeds in the coastal zone of Algeria, while in the Saharan oases (Bou Saada, El Golea, Beni Abbés, Laghouat, Timimoun), it lives on rose bushes and on vines. It does not occur farther south.

Breeding in captivity was very successful, but attempts to obtain a gregarious phase failed. It is an extremely stable species, not liable to variation.

Feeding occurs mainly about 11 a.m. and during warm, light nights. Maturing adults feed abundantly on dry food, such as bran and even hay, but during oviposition they should have leaves of blackberry, cabbage, cotton, rose, vine, as well as ripe juicy fruit. Oviposition in cages occurs usually at night, in soil at a temperature of 26-32°C. For good incubation, the soil should consist of $\frac{3}{4}$ ordinary soil and $\frac{1}{4}$ sand, and attention should be paid to watering. This is best done by pouring water through a funnel with a long spout reaching deeper than the eggs, so that the soil at their level is kept moist through capillarity. Leaves of turnip cabbage, mallow and other juicy plants, as well as ripe sliced apples, provide the best food for hoppers, while the adults, two to three days after the final moult, should have blackberry, millet and cotton leaves, and bran.

Two diseases were observed. The symptoms of one were white dots on the abdomen and loss of appetite, rapidly followed by death; this was due to excessive humidity. The second disease was due to insufficient ventilation and consisted in weakness of the feet, sluggishness and sudden death.

Even if densely crowded, *A. aegyptium* remains unchanged in its behaviour. The only observed case of excitement was during a long spell of sirocco which caused commotion amongst *A. moestum* in a near-by cage, while *A. aegyptium* merely started walking about in their cage.

Anacridium moestum, Serv.

The first two pairs of *A. moestum* were brought by M. Murat from the French Sudan. They were placed in a cage with the temperature at 35°C. and moist soil which was kept warm. Leaves of acacia, mimosa, cabbage and millet were not touched. The insects were sluggish, but one case of copulation was observed. After three days only one female remained alive. She was placed in a large glass cage with a variety of green food, from which she chose almond leaves. These were regularly supplied twice a day, and the female became stronger, fed well, laid eggs and died. About 70 hoppers hatched eventually, and by the time they became adult, twenty more adults arrived from the Sudan. During the five years of breeding, there were sometimes as many as 500-1,500 individuals in the cage.

A. moestum begins its day by basking in the sun. The favourite posture in the cage is head downwards. The glass cage was about 2 metres long, one broad, and 1.5 metres high; it was heated by electric resistance heaters under its floor and two arc-lamps burned inside at night. The floor had a false bottom of zinc plate, with holes to take cylinders with soil for oviposition; one-quarter of the false floor was of wire-netting, under which there were trays filled with water. Grass was placed on the netting and the adults liked to sit there.

Abundant food was given—branches of almond, magnolia, cotton and blackberry; on very hot days, fruit, such as apples and grapes, was given. During the day the insects merely nibbled, but they commenced to eat voraciously about 11 p.m. For the young hoppers, the food (grass, cotton, almond) was placed on a tray with very moist sand.

Oviposition occurred mostly at night, with the air temperature at 34–35°C. and that of the soil 28–34°C.; most eggs were laid in the soil at 32°C. At that temperature, hatching occurred in 39–40 days. Delayed hatchings were due to the use of cold water, to excessive watering, or to incorrectly prepared soil, the best mixture being $\frac{3}{4}$ sand and $\frac{1}{4}$ soil, well mixed and dried in the sun before use. The soil should be watered through funnels, twice daily, in the morning and before night.

The commonest disease of *A. moestum* was a gradual weakening of the muscles followed by rapid death. It began with the appearance of a pink spot between the eyes and reddening of the frons, then of the whole body. Death occurred 10–30 days later. The epidemic could be stopped and the affected insects cured by transferring them to another cage which should be kept for 2–3 days in the open, under the sun, and moved into the heated insectarium for the night. Sick individuals should be given, with their ordinary food, branches of pine, eucalyptus, bay leaves and plenty of bran, but no fruit. The cage should be opened for ventilation for 2 hours every day.

The second disease manifested itself by white mould on the abdomen, followed by loss of appetite and drying-up of the host. This was due to excessive air humidity, or to the food being moist from dew or rain.

Any sluggishness of the insects was regarded as a bad sign, and had to be dispelled if mortality was to be prevented. This was achieved by three methods:

1. About 30–40 pairs of *Locusta migratoria* were added to the cage population and the temperature raised to the point when these became agitated and induced *A. moestum* to some activity.

2. One side of the cage was strongly heated, the other ventilated.

3. One day's fasting (for adults only), then only bran and hay were given at a temperature of 30–32°C.; this was followed by suddenly raising the temperature to 34°C. and giving an abundance of green food. The temperature at night should not be below 34°C.

A. moestum could be induced to great activity at 35°C. if a hot draught was passed through the cage and repeated after 15 minutes interval.

Schistocerca gregaria, Forsk.

It is possible, by properly arranged breeding, to obtain either the solitary or the gregarious phase of this species. In our insectarium we have been able to rear at the same time up to a hundred of the solitary and up to 7,000 of the gregarious individuals.

Solitary Phase. Solitaries required cages with plenty of light and sunshine, and a moderate temperature of 25–27°C. Their cages were 25 × 25 cm. at the base and 40 cm. high. Five of them in a row formed a nest, the cages being separated

from each other by matt white, or greenish glass ; front, with the door, was also of matt glass and the top and one side were of wire-netting. The floor was of zinc, with holes for the egg-laying cylinders ; under this floor there was a tray with water, or wet sand. Electric heaters were under the lower floor. In dry weather, a fine spray of water inside the cage was used.

Food for solitaries should be varied and juicy ; leaves of cabbage (given in small quantities, but often), millet, grasses, bran and sometimes leaves of almond and peach. They should always have bay leaves and those of eucalyptus (or fir) ; branches of these trees were fastened under the ceiling of the cage and changed twice a month ; this food prevents diseases. After the final moult, food should be changed and the insects should get plenty of grass, bran, mint, millet and eucalyptus.

In order to obtain pure ph. *solitaria*, the following conditions must be observed :—

- (1) When changing food, etc., all sharp, sudden movements should be avoided.
- (2) Food should be changed frequently.
- (3) Humidity should be kept high.
- (4) Temperature should not fluctuate too much, *e.g.*, 25–27°C. during the day and 19–21°C. during the night.
- (5) The cages should be kept scrupulously clean and well ventilated.
- (6) The insects should be “entertained” from time to time without being agitated. This is achieved by stroking the outside of the cage with a large feather, by warming one side of the cage with an electric bulb, or by providing a cool draught.

The solitaries were very inactive at 35°C., and when gregarious individuals would fly excitedly about the cages, solitaries exhibited their agitation only by moving the hind legs and by changing their position.

Gregarious Phase.—Gregarious locusts were reared in large cages 90×100 cm. at the base and 150 cm. high. The floor was divided into two parts. One part was of two zinc plates, on which sand and food were placed. The second was covered by perforated zinc and under it were placed four oviposition trays, 15 cm. deep, with a 2–3 cm. layer of gravel on the bottom (which was finely perforated), the rest filled with a mixture of $\frac{1}{3}$ fine oil and $\frac{2}{3}$ fine river sand. The soil was watered through long funnels. When there were about 40 egg-pods in a tray, it was removed and placed in a thermostat at 32–33°C. Hatchings were excellent, and we had up to 4,000 small hoppers at the same time.

Food for hoppers consisted of turnip, cabbage, dandelion, maize and millet. Adults during the first few days ate a lot of green food, but after six days and while they remained pink, their main food was bran, dry hay, grasses and cotton leaves ; when the yellowing begins they should be given navet, cabbage and dandelion. If the weather is very dry, juicy fruit should be given and the sand on the floor moistened.

The moulting of hoppers occurred mostly on the walls of the cage, and cases of cannibalism were frequent. To avoid this, bunches of plants were placed in the corners of the cage. When many hoppers are moulting, draughts should be avoided, as these tend to dry the moulting individuals, which tried to avoid drying by crawling into dark, damp crevices.

Considerable mortality was usually due to neglect, *e.g.*, when locusts were permitted to eat their excreta with the bran ; when ventilation was insufficient ; or when water in vessels, in which bundles of food were placed, was permitted to get foul. Mortality from diarrhoea could be avoided by adding leaves of mint, eucalyptus or nasturtium to the food, and by leaving out turnip and cabbage. In the best broods, not more than 7 per cent. mortality was observed.

Good gregarious forms could be obtained if the locusts were (1) abundantly fed ; (2) moved about a good deal ; and (3) had ample opportunities for basking. The cages should be built in such a way that there should be plenty of sun on the floor.

Schistocerca paranensis, Burm.

Rearing of this species (received from Argentina) was carried out in the same manner as that of *S. gregaria*, but the preferred food was grass. It is a very hardy species, and the percentage of mortality was low.

Locusta migratoria, L.

This species (from Algeria and Southern France) was bred for about 7 years in the cages as described for *S. gregaria*, kept at 24–32°C. As food it received grasses, *Phragmites* and bran, and for oviposition a mixture of equal parts of soil and sand was used.

Up to 2,000 hoppers were kept in one cage and hoppers were of gregarious colouration, but adults never reached the typical ratios of the ph. *gregaria*.

In order to induce excitement, sharp fluctuation of temperature should be arranged, *e.g.*, the cage should be warmed up to 34°C., then sprayed with cold water, or short, frequent cold draughts provided.

The following notes illustrate the conditions causing activity in adults :—

27.xi. 5 p.m. Temperature 30°C. ; relative humidity 60 per cent. ; light cloudiness. Draught through the cage provided, causing flight.

2.xii. Temperature 30°C. ; relative humidity 61 per cent. ; sky overcast. Excitement lasting two hours.

8.i. 11.40 a.m. Temperature 32°C. ; relative humidity 63 per cent. ; sky overcast, but intermittent sunshine. Draught provided, causing a drop in temperature and fluttering of wings. Cage covered by cloth ; temperature rose to 33°C. ; strong flying activity, lasting some time.

NEW BRACONID PARASITES OF AUSTRALIAN WOOD-BORING BEETLES
WITH NOTES ON THE SUBFAMILY HECABOLINAE (HYM., BRACONIDAE).

By G. E. J. NIXON, B.A.

Imperial Institute of Entomology.

This paper has been written in response to a request for determinations of certain parasites of wood-boring beetles in Queensland, Australia. The description of a new species of *Monolexis* entailed rather more research than was expected and has led to the expression of a few opinions of an exploratory nature on the status of the subfamily HECABOLINAE. Altogether one new species in the DORYCTINAE and six (including one new genus) in the HECABOLINAE are described.

The types of all new species are in the British Museum.

DORYCTINAE.

Doryctes laemosacci, sp. n.

♀. Head and thorax bright fulvous; sometimes the propodeum slightly infuscated above; abdomen above black-brown. Scape and pedicel fulvous; flagellum dark brown but becoming almost yellowish on about apical third. Front and middle legs pale like the thorax; hind legs dark brown virtually throughout. Wings rather strongly smoky throughout; stigma evenly dark brown.

Head from above as in figure 13. Face rather indefinitely rugose-punctate. Vertex and temples strongly shining, smooth except for sparse punctures, the intervals between which are equal more or less to the diameter of an ocellus. Ocelli in a triangle with base much longer than sides; posterior pair margined by a short, deep, curved groove externally. Antenna broken but at least 30-segmented; scape simple; flagellum clothed with short brownish pubescence; segment 1 of flagellum a trifle longer than 2, in no way modified. Eyes large, their longer diameter about $3\frac{1}{2}$ times as long as the malar space. *Thorax* rather short and deep. Pronotal collar very short, lying far below the level of the mesonotum, its anterior margin deeply widely emarginate. Mesonotum somewhat truncate in front, falling perpendicularly to the pronotum; notaulices very deep anteriorly, thus emphasising the convexity of the lobes; posteriorly they converge onto a slightly hollowed out area covered with sunken rugosities which consist chiefly of punctures of various shapes and sizes with polished intervals; the rest of the mesonotum is vaguely punctate on a polished surface; its hairs are very numerous, scattered fairly evenly over its entire surface and posteriorly they become slightly longer; in two out of the three specimens the middle lobe has a fine percurrent furrow. Scutellum polished, sparsely punctate. Propodeum with well defined dorsal areas which are about as long as wide and are margined by a carina which is nowhere angled. Mesopleura impunctate, below with short, smooth, wide furrow. Hind coxa roundly angled beneath at base; hind femur short and decidedly thick (fig. 3); outer apical margin of hind tibia with about 8 stout reddish spines which are set well back from the actual edge of the tibia. Hairs of the upper surface of the hind tibia semi-erect, about $\frac{2}{3}$ to $\frac{3}{4}$ the middle width of the tibia; hind tarsus 1 slightly less than twice 2, 12:7. Wings (fig. 15); 1st abscissa of the radius as long as the 2nd, or a little shorter. *Abdomen* broadly oval, $1\frac{1}{2}$ times as long as wide; tergite 1 as long as apically wide; in the largest specimen it is coarsely striate-punctate but in the two smaller examples the punctate element is much reduced and the surface appears as irregular, broken striation; rest of the

abdomen smooth and polished; tergite (2-3) covers fully $\frac{2}{3}$ of the surface of the abdomen beyond tergite 1 and its suture shows as a fine line; also, tergite (2-3) has a slender, ill-represented lateral margin extending almost to apex; other tergites unmarginated and each with a row of long setae. Ovipositor sheaths projecting beyond the apex of the abdomen by a distance equal to about half the length of the abdomen.

Length: 3-4.5 mm., without ovipositor.

AUSTRALIA: Queensland, Emu Vale, 10.ii.1939, 3 ♂♂, bred from *Laemosaccus* sp. (Curculionidae). (A. R. Brimblecombe).

A rather strikingly coloured species, characterised to a large extent by the polished lobes of the mesonotum with their sparse punctures. The very short 2nd cubital cell is also characteristic but it is to be expected that this shortness will turn out to be a feature of a group of species.

HECABOLINAE.

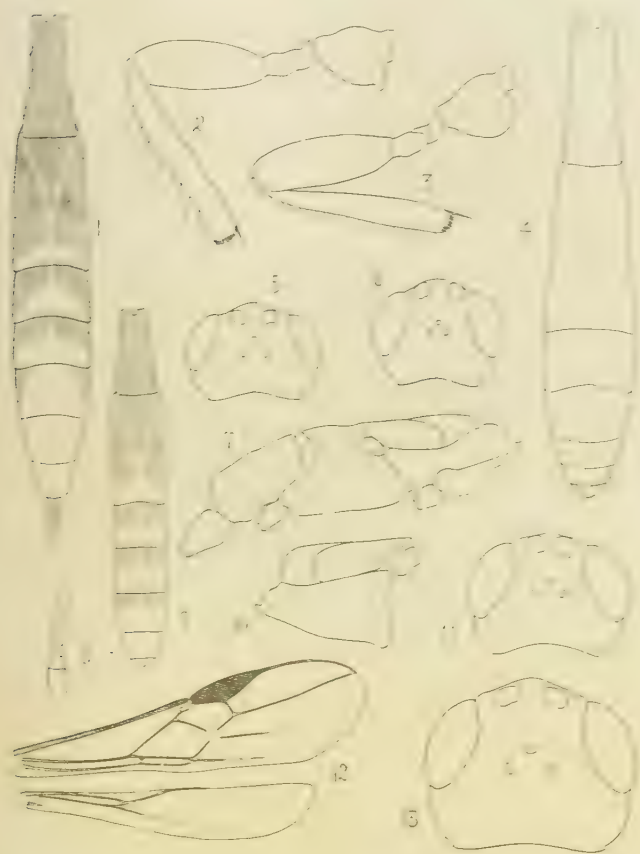
Writers have separated the HECABOLINAE from the DORYCTINAE primarily on the number of cubital cells in the fore wing: the former group is considered to have two, the latter three. Further support for the separation of the two subfamilies has been found in the possession of a false stigma in the hind wing by the males of some genera of the HECABOLINAE. But I do not think this character can be thus used, for similar venational modifications occur in both the related subfamilies DORYCTINAE (*Dendryctes*, for example; Nixon, 1939) and SPACHININAE (certain Oriental species of *Spachinus*; Nixon, 1943).

Hence the sole character which divides the HECABOLINAE from the DORYCTINAE as at present constituted and which can form the basis of an investigation of their systematic status seems to be the number of cubital cells in the fore wing. The second cubital cell of the DORYCTINAE is not always sharply defined because its distant limiting vein, the second transverse cubitus, may be and often is, colourless. Its origin on the radius and cubitus, however, is always indicated by an angle or at any rate a kink on each of these two veins so that no confusion with the HECABOLINAE need arise. *Helictes* Marshall, which I have already shown is a Doryctine genus (1938), was wrongly placed in the HECABOLINAE by Marshall almost certainly because he assumed the type to be white and thus observing the presence of the two transverse cubital veins.

The definition of the HECABOLINAE has a fluidity due, not so much to a failure to define the presence of one or the other of these two transverse veins, as to the absence of a clear idea of how the two cubital cells are to be made up. Is it the first (*Heterogynis* Haliday, fig. 14) or the second transverse cubitus (*Heuctilus* Curtis, fig. 18), which is to be absent? Scapheti includes both types of genera in the subfamily.

I consider that only genera in which the second transverse cubitus is completely suppressed, there being no break in the continuity of the second abscissa of the radius, to suggest the origin of such a vein—should be included in the subfamily. This will not necessarily bring together genera which are naturally related but it will give the HECABOLINAE a cohesion which it has lacked up to now and furthermore will keep it, as far as venational structure goes, within the limits which form the essential characteristics of the type of the subfamily, *Heuctilus caucasicus* Curtis (fig. 18).

It has not been possible for me to study all the genera which Scapheti has grouped together in the HECABOLINAE (Ann. Ent. Beauriville, p. 54). But I am giving figures of wings of those which have been available so that their interrelationships—on the basis of venation, for it be emphasised—can be better understood. It will be evident from a study of these wings that they have (except fig. 14) one feature in common: the complete absence of the second transverse cubital vein. Apart from this there



Figs. 1-13. 1. *Eucorystes tenuis*, sp. n., abdomen of ♀; 2. *Heterospilus asion*, sp. n., hind leg of ♀; 3. *Doryctes laemosacci*, sp. n., hind leg of ♀; 4. *Terate menopon*, gen. et sp. n., abdomen of ♂; 5. *Heterospilus asion*, sp. n., head of ♀ (dorsal); 6. *E. remus*, sp. n., head of ♀ (dorsal); 7. *E. remus*, sp. n., thorax of ♂ (lateral); 8. *T. menopon*, first three antennal segments of ♂; 9. *E. remus*, abdomen of ♂; 10. *T. menopon*, anterior part of thorax of ♂ (lateral); 11. *H. asion*, head of ♂ (dorsal); 12. *Analytus celestes*, Nixon (1938, India), wings of ♀; 13. *D. laemosacci*, head of ♀ (dorsal).

seems to be no detail of structure which would divide these genera as a whole from the DORYCTINAE. Certainly the genus *Interpret* as *Mesochorus* has many *Interpret* characteristics that were it not for the evidence of the fore wing it would find a natural place among groups of genera now included in the DORYCTINAE. It should not be ruled out that the complete absence of the second transverse cell may possibly occur in genera of true Doryctine stock. That is a matter which can be decided only when both subfamilies have been exhaustively studied.

Heterospilus asion, sp. n.

♂♀. Dark brown to the naked eye with the abdomen beyond the petiole pale brown. Head, mesonotum, lower part of the mesopleura and the mesosternum medium brown; sides of the thorax otherwise, propodeum and scutellar region blackish; in the ♂ the whole of the abdomen, except the sculptured part of tergite (2+3) is dark brown. All the coxae, femora and tibiae, except the narrowed basal portion of the last mentioned, which is almost colourless, dark brown. Scape, pedicel and first two or three segments of the flagellum same colour as the head. Wings markedly smoky; stigma more or less evenly dark brown throughout.

♀. Head from above as in figure 11. Face transversely striate-rugose with a smooth, slightly raised line down the middle. Frons finely striated, almost flat and, in a lateral view of the head, almost at right angles with the vertex. Ocelli situated on anterior brow of vertex in a triangle with base fully twice as long as sides; a line joining the anterior edge of the posterior ocelli almost touches the posterior edge of the anterior ocellus; the latter lies on the plane of the frons. Eyes large, their longer diameter nearly $2\frac{1}{2}$ times the length of the malar space. Vertex somewhat dull, finely scaly-reticulate. Antenna with 32-33 segments ($3\frac{1}{2}$); scape simple, in lateral view only a little longer than wide apically; flagellum thin; segment 1 about $1\frac{1}{4}$ times as long as 2, slightly curved, slightly widened and smooth and slightly flattened on the inner side of the curve. Thorax: Pronotal collar very short, simple. Mesonotum somewhat truncate in front, raised high above the level of the pronotal collar to which it falls perpendicularly; notaulices deep, rugose, converging on to a sunken rugose area which may or may not have an ill defined medial keel; surface of the lobes dull, with a broken scaly-reticulation which shows well marked transverse elements and which, more especially on the middle lobe, resembles the surface of a file; further, the mesonotum is thickly covered all over with short hairs. Scutellum dull, very closely scaly-reticulate all over. Propodeum with a well defined keel extending a little beyond middle; dorsal areas sharply defined, more or less shagreened over most of their medial part but becoming reticulate around sides; a little longer than wide; spiracle small, inconspicuous, situated right on keel which separates propodeum from metapleura. Mesopleura below with a wide, shallow depression which sometimes shows a line of feeble rugulosity along bottom; convex area above depression dull, shagreened. Hind coxa with a well developed dentiform projection beneath at base; all the femora short and rather thick; hairs of the upper surface of the hind tibia slightly longer than its middle width (fig. 2); outer apical margin of the hind tibia with about 8 stout spines; segment 1 of the hind tarsus less than twice as long as 2, 18:11. Fore wing (fig. 14): 1st transverse cubitus obliterated except for a spur on the radius; disco-cubitus strongly curved; basalis decidedly thick; nervus parallelus interstitial. Abdomen: Tergite 1 only a little longer than apically wide, 7:6, much widened to apex and with strong striate-punctuation which towards apical half of segment is convergent towards the middle line; tergites (2+3) 6 widely emarginate but at first sight appearing deeply emarginate; this is due to the surface of the tergites anterior to the actual emargination being feebly depressed; tergite (2+3) with a sharply delimited basal area, which is rounded apically at sides and has a sculpture similar to that of tergite 1 but finer and with the striate element less well marked; rest of the abdomen completely smooth; apical tergites each with a row of long outstanding cilia; tergite (2+3) margined laterally as far as the second spiracle. Ovipositor sheaths projecting beyond the apex of the abdomen by a length equal to slightly less than that of the abdomen.

Length: 3.5-4 mm., without ovipositor.

♂. Like the female except that tergite 1 is slightly longer and narrower. No trace of a false stigma in the hind wing.

AUSTRALIA: Queensland, Imbil, 18.ii.1937, 2 ♀♀, one the type, bred from *Xylocopa gibbicollis*, MacL. (Bostrychidae) (A. R. Brimblecombe); Maryborough, 3.xi. 1936, 4 ♀♀, 2 ♂♂, bred from *X. gibbicollis* (A.R.B.).

I place this species provisionally in *Heterospilus*. Apart from venation, there is nothing to separate it structurally from the genus *Doryctes*.

***Monolexis atis*, sp. n.**

♀. Medium brown to the naked eye; lateral lobes of the mesonotum dark brown to blackish; middle lobe less deeply infuscated than the lateral ones. Legs throughout pale honey brown, paler than the pale parts of the body. Wings faintly brownish; stigma more or less evenly dark brown throughout.

♀. *Head* from above as in figure 5. Face with fine, somewhat broken striation which fades out along the middle line. Frons and vertex smoothly, transversely striate. Antenna with 26 segments (1 ♀); scape simple, about $1\frac{1}{2}$ times as long as wide at apex; flagellum thin; segment 1 without modification, as long as 2. Ocelli in a triangle with base very slightly longer than sides. Eyes moderately large, their longer diameter $2\frac{1}{2}$ times as long as the malar space. *Thorax*: Pronotal collar simple, lying far below the level of the mesonotum; mesonotum somewhat truncate in front, with prominent "shoulders," falling perpendicularly to the pronotum; lobes rather shining, especially the lateral ones, and with a very superficial sculpture which shows a well marked transverse tendency; notaulices deep, rugose, converging on to a rugose area, the sculpture of which, in smaller specimens, may show well marked longitudinal elements; pubescence of mesonotum consisting of decumbent hairs which are absent over most of the surface of the middle lobe and on the darkened parts of the lateral lobes. Scutellum a little flattened, shining and with feeble scaly-reticulation. Propodeum irregularly reticulate-rugose without delimited dorsal areas and with only a trace of a basal carina at extreme base; on each side of this vestigial carina, the surface tends to become smooth and unsculptured. Fore wing: recurrens entering extreme base of 2nd cubital cell; nervus parallelus arising from lower distal corner of 2nd discoidal cell (fig. 16). Mesopleura over most of its medial convex part smooth and shining; furrow wide, smooth. Legs: hind coxa with a tooth-like projection beneath at base; hairs of the upper surface of the hind tibia semidecumbent, about $\frac{1}{2}$ as long as the middle width of the tibia; outer apical rim of hind tibia without differentiated spines; hind tarsus 1 slightly less than twice 2, 11:6; 3 is $1\frac{1}{2}$ times as long as 5. *Abdomen*: Tergite 1 seen from the side steeply curved at base; seen from above, about $1\frac{1}{2}$ times as wide at apex as at base, not much longer than apically wide, 5:4, striate-rugose, the striate element less in evidence broadly along the middle, especially in larger females; tergite (2+3) with a striate basal area which has a bisinuate apical margin; apical part of tergite (2+3) with a band of sculpture at base which varies much in definition but is widest at the sides and is throughout separated from the basal area of tergite (2+3) by a narrow smooth space; rest of the abdomen smooth, markedly convex; tergite (2+3) margined laterally throughout; more apical tergites with a row of very short, inconspicuous cilia. Ovipositor sheaths projecting beyond apex of abdomen by a length equal to that of abdomen+thorax.

Length: 2.3-4 mm., without ovipositor.

♂. Like the female except for the usual sexual differences but apparently more variable in size in the small series studied, the length ranging from about 1.5 mm. to about 3.8 mm. The genitalia are very large for the size of the insect. Hind wing without a trace of a stigma.

AUSTRALIA: Queensland, Atherton, 1 ♀, the type, 1 ♂, bred 27.ii.1934, from *Lycius brunneus*, Steph. (Lectidae), (*D.O.L.*); Palm Is., 1 ♀, 3 ♂♂, from *L. brunneus* (G. Brooks); N. Queensland, 1 ♀, 7 ♂♂, bred from *L. brunneus* on *Xanthophyllum macintyrii*, F. Muell. (*A. R. Brimblecombe*).

This species is certainly correctly placed in *Monolexis*, Forst., in the sense in which Marshall interpreted the genus; so much is clear from the description and figure of

gives of his *M. försteri* (Hym. d'Eur, vol. 5 bis, p. 105 & plate 5). It is possible that my new species is a European insect which has been introduced into Australia with *Lyctus brunneus* for I have examined a single specimen, a female (Italy, Portici, bred from Bostrychid on fig) which appears to be identical with *atis*. That *atis* is an Australian species must therefore be accepted with reservation.

It also resembles extremely closely a series of specimens in the British Museum received from North America and labelled by Dr. C. F. W. Muesebeck of the U.S. Bureau of Entomology as *Monolexis lycti*, Cresson (originally *Heccabolus lycti*, Cresson; I can find no reference of the transference to *Monolexis*). This series of specimens was reared with an adult *Lyctus* sp. They differ from the Australian specimens only in being smaller, much paler in colour (almost uniformly fulvous red) and in having the 3rd segment of the hind tarsus hardly longer than the 5th.

***Monolexis sorus*, sp. n.**

♀. Entirely pale fulvous to the naked eye. All the coxae and the basal trochanter yellowish white; legs otherwise pale honey yellow. Wings almost hyaline; stigma brown, faintly paler at extreme base. Scape, pedicel and one or two basal segments of the flagellum pale like the head.

♀. *Head* from above much like that of *atis* (cf. fig. 5) but the eyes larger, their longer diameter a little more than $2\frac{1}{2}$ times as long as the malar space, 8:3, almost circular (in *atis* they are very distinctly oval). Face feebly rugulose, becoming smoother broadly along the middle line. Frons and vertex finely smoothly aciculated. Antenna with 19-21 segments ($2\frac{1}{2}$): scape simple, about $1\frac{1}{2}$ times as long as apically wide; flagellum 1 without modification, as long as 2. Ocelli in a triangle with base very slightly longer than sides. *Thorax*: Pronotal collar simple, lying far below the level of the mesonotum. Mesonotum somewhat truncate in front, with prominent "shoulders," falling perpendicularly to the pronotum; lobes faintly shining, with a rather uneven scaly-reticulate surface sculpture; hairs short, decumbent, more evenly distributed than in *atis*, so that the lateral lobes do not appear bare along the middle by contrast; notaulices rugose, converging on to a sunken rugose area in which longitudinal elements are usually clearly defined. Scutellum flattened, almost smooth. Propodeum: no clearly defined basal carina, a line of rugosity taking its place; dorsal areas almost smooth and slightly longer than wide: they are bounded externally by a fine keel but their posterior limits are vague. Mesopleura smooth over most of its surface and below with a smooth wide furrow. Legs: hind coxa with a dentiform projection beneath at base; hairs of the upper surface of the hind tibia very sparse, semi-erect, about half as long as the middle width of the tibia; outer apical rim of the hind tibia with a row of differentiated spines; hind tarsus 1 is $1\frac{1}{2}$ times as long as 2; 3 distinctly a little longer than 5, 11:9. Wings: 2nd discoidal cell rather widely open at apex; subcostella of the hind wing virtually obliterated distal to where it is contiguous with the wing margin.

Abdomen: Tergite 1 is $1\frac{1}{2}$ times as long as apically wide and about $1\frac{1}{2}$ times as wide at apex as at base (between the glymmae), longitudinally striate, the ridges not very close, somewhat wrinkled, the intervals rugulose; tergite (2+3) with a semicircular striate area at base, the ridges a little more even than on tergite 1, but the intervals equally rugulose; rest of tergite (2-3) and the whole of the remaining tergites smooth; further, tergite (2-3) is margined laterally virtually throughout and its suture is indistinctly bisinuate; all tergites except 1st with a row of very short, inconspicuous cilia. Ovipositor sheath projecting beyond apex of abdomen by a length slightly shorter than body less head.

Length: 1.9-2 mm., without ovipositor.

♂. Like the female except for the usual sexual differences, but antenna with 14 and 16 segments (2 exs.). No trace of a stigma in the hind wing.

MALAYA: Selangor, Kepong, 2 ♀♀, one the type, 1 ♂, bred 1937 from *Minthea rugicollis*, Walk. (Lyctidae) in plywood; 2 ♂♂, 1 ♀, emerged from borings in plywood, probably made by *M. rugicollis* (Forestry Department).

This little species differs most readily from *atis* in size, colour and the absence of sculpture on tergite (2+3) beyond the basal sculptured area.

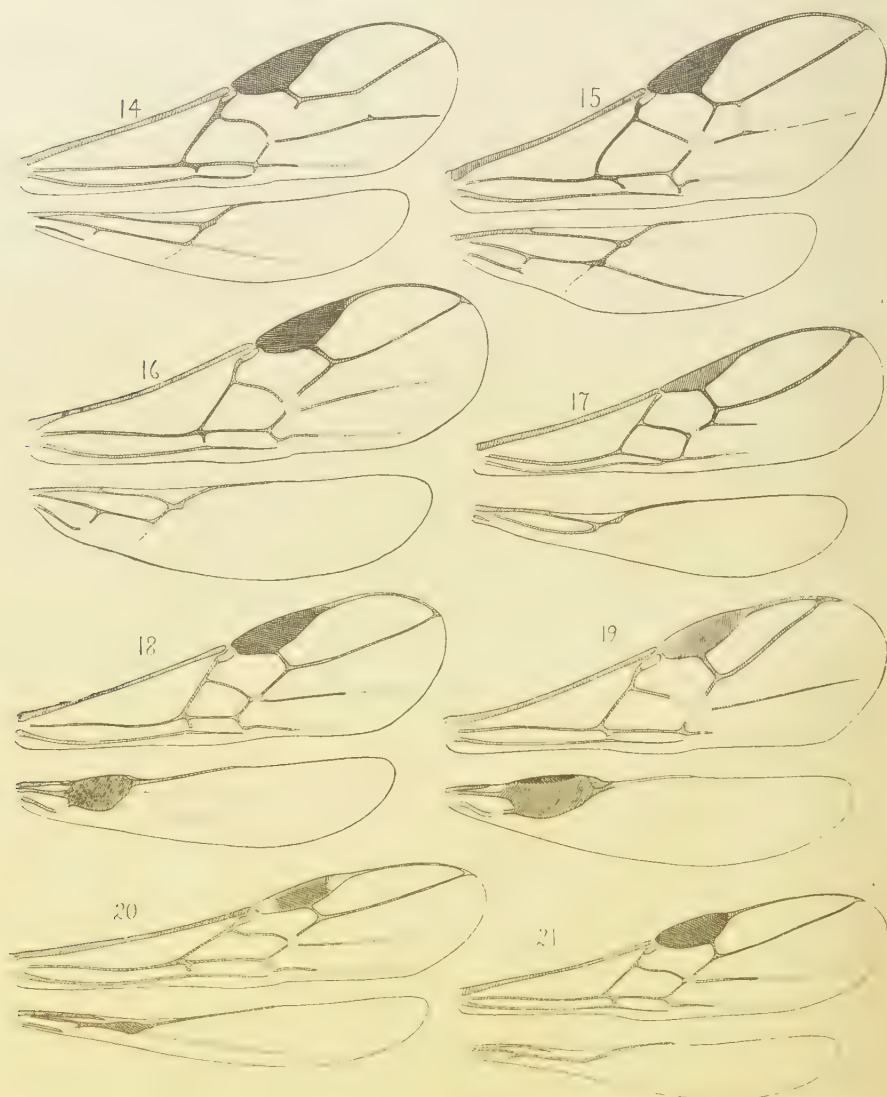
Eucorystes remus, sp. n.

♀. Very slender species. Head pale fulvous; thorax pale in front but becoming darker behind, the propodeum and metapleura being more or less black; the pronotum is suffused with darker brown across the collar; mesonotum virtually fulvous all over, at most a little darker within the posterior rugose area; lower part of the mesopleura and the entire mesosternum pale; abdomen marked with dark brown and yellowish as in figure 9. Legs yellow, except for the apical tarsal segment which may be darkened. Wings almost hyaline; stigma dark brown throughout.

♂. Head distinctly a little narrower behind the eyes than across them and a little flattened dorso-ventrally. Face with feeble transverse striation. Frons with vague scaly-reticulation. Vertex towards and to the sides of the ocelli more or less scaly-reticulate; on about posterior half this sculpture becomes broken transverse aciculation; in small examples, the vertex is virtually smooth. Ocelli small, in a triangle with base slightly longer than sides. Antenna with 22-29 segments; scape simple but markedly elongate and measured on its outer side about $1\frac{3}{4}$ times as long as apically wide; flagellum 1 hardly longer than 2, not obviously bent on its outer side and with fine pubescence here. Thorax conspicuously flattened dorso-ventrally, about $2\frac{1}{2}$ times as long as wide when measured from above (fig. 7). Pronotal collar $\frac{1}{3}$ the length of the mesonotum, much swollen transversely, more or less on a level with the mesonotum and with a feeble transverse keel anterior to middle; posterior to this keel rather short, bristly hairs present, directed mostly backwards. Mesonotum only very feebly inclined in front, its lobes, owing to the flatness of the thorax, not sharply defined as separate convexities; posteriorly the mesonotum has a large V-shaped or oblong area of close reticulate-rugosity which extends forwards beyond middle; lobes otherwise dull, subscaly-reticulate; notauli weakly impressed and defined only where they have lateral direction; mesonotal hairs absent from the middle part of the lobes; those along the outer edge of the rugose area, i.e. along the undefined notaulic courses, directed outwards almost at right angles to the long axis of the body. Scutellum flat, finely rugose and with clearly defined longitudinal elements in most examples. Propodeum without areolation and with a feeble basal carina, edged with reticulate-rugosity; otherwise with irregular punctate-reticulation; the surface on each side of the medial rugose area tends to be less strongly sculptured and is sometimes almost smooth. No carina between the propodeum and the metapleura. Mesopleural furrow narrow, smooth and running the whole length of the mesopleura; the surface above the furrow smooth, shining and bare. Legs: hind coxa without a trace of a projection beneath at base; hairs of the legs long, sparse, those on the upper surface of the hind tibia about $1\frac{1}{4}$ times as long as its middle width, semi-erect; no spines on outer apical rim of hind tibia; hind tarsus 1 a little less than twice 2; 3 as long as 5; front tibia with a row of about 6 inconspicuous spines along outer edge. Wings very narrow (fig. 21); radius leaving stigma at a considerable distance distal to middle; angle between 1st and 2nd abscissae of radius slightly less than 90 degrees; nervus parallelus not interstitial; no trace of a stigma in the hind wing; subcostella of the hind wing obliterated beyond middle. Abdomen long, narrow (fig. 9); tergite 1 about $1\frac{1}{2}$ times as long as apically wide, striate-reticulate but the striate element decidedly feeble; tergites (2+3) 5 becoming progressively more finely striate-reticulate; suture of (2+3) deeply impressed but narrow, present only at sides; anterior to the suture tergite (2+3) shows two pale lines originating at the basal corners and converging towards the middle of the segment, these pale

lines are further emphasised by a fine keel which runs within their entire length; tergites (2-3)-6 with a completely differentiated lateral margin; hairs of tergites 4 and 5 long, sparse and more or less evenly distributed over their entire surface.

4. Antenna with 34 segments. Tergite 1 in the single example slightly deformed but certainly wider and less elongate than in the male. Visible part of the ovipositor, measured from above, as long as the abdomen.



Figs. 14-21. Wings of:—14. *Heterospilus asion*, sp. n., ♀; 15. *Doryctes laemosacci*, sp. n., ♀; 16. *Monolexis atis*, sp. n., ♀; 17. *Ecphylus silesiacus*, Ratz. (1848), ♂; 18. *Hecabolus sulcatus*, Curtis (1834), ♂; 19. *Hecabalodes anthaxiae*, Wilkinson (1929, Sudan), ♂; 20. *Terate menopon*, gen. et sp. n., ♂; 21. *Eucorystes remus*, sp. n., ♂.

Length : ♂, 2.5–4.2 mm. ; ♀, 4.2 mm., without ovipositor.

INDIA : U.P., Dehra Dun, Phanduwalla, 26.30.iii.1929, 10 ♂♂ (one ♂ the *type*, 30.iii.), 1 ♀ bred from wood of *Mallotus philippinensis*, Müll.

I place this species and the next in *Eucorystes* with confidence, although the British Museum possesses no specimens of *aciculatus*, Reinhard, the genotype, and until now the only species in the genus. Reinhard's description of *aciculatus*, a European insect, is very careful and the figure he gives of it, though clearly not accurate in all respects, suggests a species not unlike *remus* itself. The genus seems to be characterised chiefly by the converging furrows on tergite (2+3).

Eucorystes tenuis, sp. n.

♀. Differs from *remus* as follows :—

A species of much more slender build. Virtually the entire dorsal surface of the thorax dark brown, the ventral surface pale brown ; brown areas of tergites 4–6 and of the apical part of (2+3) more extensive laterally but less sharply delimited along the middle line (fig. 1).

Head slightly less transverse (fig. 6). Eyes a little larger in a dorsal view of the head. Ocelli almost in an equilateral triangle. Frons and vertex without scaly-reticulation, only vague aciculation being present. Antenna longer and more slender but with the same number of segments—34; pubescence of flagellum on outer side so excessively short that the segments appear bare ; in *remus* the pubescence is more readily visible here. Pronotal collar slightly longer in proportion to the length of the mesonotum, more swollen, more bristly and without trace of a transverse keel in front of middle. Hairs of the mesonotum much shorter, much more numerous, adpressed and covering the entire surface of the lobes. General disposition of sculpture of propodeum as in *remus* but the punctate element more emphasised ; the propodeum itself slightly longer than wide at base, 27 : 25 ; in *remus* ♀ it is very slightly wider than long, in the ♂ as long as wide. Hairs of the legs longer, those of the upper surface of the hind tibia about $1\frac{1}{3}$ times as long as its middle width. Stigma emitting radius at middle : 1st and 2nd abscissae of the radius forming an angle of slightly more than 90 degrees ; subcostella of the hind wing complete throughout (the unique female of *remus* has the hind wings missing but *cf.* hind wing of male, fig. 21). *Abdomen* longer and narrower (fig. 1) ; tergite 1 about $2\frac{1}{3}$ times as long as apically wide, sculptured as in *remus* ; tergite (2+3) more or less parallel-sided, almost twice as long as apically wide but appearing still longer ; exposed part of tergite 8 as long as apically wide. Ovipositor much longer, projecting beyond the apex of the abdomen by a length equal to that of the abdomen.

Length : 5.3 mm., approx., without ovipositor.

INDIA : U.P., Dehra Dun, 1 ♀, bred 12.v.1930, “*ex dry stems*” (*J. C. M. Gardner*).

The most obvious differences between this species and *remus* lie in the point of emission of the radius, the pubescence of the mesonotum and the length of the ovipositor.

Terate, gen. nov.

♂. Slender species. *Head* of simple form, that is, no trace of flattening as in the two species of *Eucorystes* described above. Scape of antenna simple, not elongate ; segment 1 of the flagellum not modified beyond being markedly bent (fig. 8). Ocelli in a triangle with base considerably longer than sides. *Thorax* long, narrow, not flattened dorso-ventrally. Pronotum lying far below the level of the mesonotum ; middle lobe of the mesonotum prominent and bulging in front, falling more or less perpendicularly to the pronotum ; pubescence of mesonotum sparse and quite inconspicuous. Propodeum without areation and without longitudinal carinae,

irregularly reticulate; no separation between metapleura and propodeum. Mesopleural furrow narrow, straight, smooth, running the whole length of the mesopleura. Legs: hind coxa with a strong projection beneath at base; hairs of the legs long and sparse; outer apical rim of the hind tibia without spines; hind tarsus 1 slightly more than twice 2; 3 longer than 5; front tibia with a row of 7-9 stout spines along outer edge. Wings: nervus parallelus not interstitial; mediella of the hind wing thickened towards apex to form a false stigma (fig. 20). *Abdomen* long, narrow; tergites 2-6 with a completely differentiated sharp, lateral margin; tergite 1 much longer than wide; suture between the fused 1st and 2nd tergite sharply defined. Wings very narrow.

Type of the genus the following species:—

***Terate menopon*, sp. n.**

♂. Head pale honey brown; thorax dark brown but beneath becoming almost as pale as the head; propodeum almost blackish; abdomen warm brown with a discrete narrow triangular area on the true tergite 2, tending to be darker; tergite 1 more or less as dark as the thorax; there is also a dark flush at the sides of both tergite 2 and 3, noticeable more especially in the paratype. Legs pale honey brown throughout. About basal third of antenna same colour as legs. Fore wings faintly darkened; stigma with a conspicuous pale area at base and apex.

Head very distinctly narrower behind the eyes than across them. Face somewhat weakly transversely rugose. Frons and vertex finely, evenly transversely striated. Longer axis of the eye $2\frac{1}{2}$ times as long as the malar space. Antenna with 35 segments; scape measured on outer side only a trifle longer than wide at apex; flagellum 1 hardly longer than 2, 13:12, bare on its outer side (the more curved side). *Thorax*. Pronotum a little swollen transversely. Mesonotum very slightly flattened; sculpture of lobes consisting of irregular scaly-reticulation; middle lobe almost truncate in front (fig. 10) and with rather prominent "shoulders"; notaulices fairly deep, margined on inner side by an irregular carina and converging on to a narrow area of longitudinal rugosity; lateral declivous portions of the lobes with some fine, rather inconspicuous pubescence. Scutellum obscured by pin. Propodeum irregularly rugose-reticulate. Mesopleura finely pubescent all over and longitudinally striated except for an almost smooth narrow area, immediately above the furrow. Radius leaving stigma very slightly beyond middle. Hairs of the upper surface of the hind tibia very sparse, about $1\frac{1}{2}$ times as long as its middle width. *Abdomen* (fig. 4): tergite 1 nearly 3 times as long as apically wide, 47:17, with strong longitudinal striations, the intervals between which are rugulose; tergite (2-3) sculptured like 1; 2nd suture sharply defined, smooth, weakly bisinuate; tergite 2 with a very feebly indicated (by a flush of darker colouring and by being very slightly more raised than surrounding surface) narrow triangular area, the apex of which touches the 2nd suture; tergite 4 sculptured like 3; 5 scaly-reticulate; tergites 4-6 with a row of cilia, the row on 4 curved, that on 5 and 6 more straight.

Length: 5.8 mm., approx.

W. AFRICA: Ashanti, Obuasi, 29.v.1907, 2 ♂♂ (*W. M. Graham*).

In spite of some well-marked differences, this genus does, I think, show an obvious relationship with *Eucorystes* as I have interpreted it. The chief points of resemblance lie in the narrow build, the venation (the presence of a stigma in the hind wing of *Terate* is probably less significant than it might appear at first sight) and the form and sculpture of the abdomen. The most important differences are the shape of the mesonotum in front and the shape of the hind coxa.

References.

- MUESEBECK, C. F. W. (1935). Synonymical notes on *Ecphylus* Foerster, with description of one new species.—Proc. ent. Soc. Washington, **37**, p. 21.
- NIXON, G. E. J. (1938). A new genus of Hecabolinae and a note on the genus *Telebolus* Marshall.—Proc. R. ent. Soc. Lond., (B) **7**, p. 152.
- WILKINSON, D. S. (1929). New parasitic Hymenoptera and notes on other species.—Bull. ent. Res., **20**, p. 105.
-

THE USE OF A PLASTER SUBSTRATUM FOR TESTING PYRETHRUM-OIL FILMS AGAINST *ORNITHODORUS MOUBATA*. MURRAY (ACARINA: ARGASIDAE).

By G. G. ROBINSON,

London School of Hygiene and Tropical Medicine.

Ornithodoros moubata is the vector of relapsing fever in Central Africa, and previous papers (Robinson 1942 a, b & c) have dealt more academically with its susceptibility to pyrethrum. The present experiments have a more practical trend and embody the use of a simple plaster model which is a convenient laboratory representation of the material which would have to be treated in field control. In Africa the ticks normally infest the huts of the natives, and the model used here may perhaps correspond to a mud floor or the mud-filling of the hut-walls. By letting ticks walk on films of insecticide applied to the plaster substratum in various ways, some idea was obtained of factors which would be important in field control.

Choice of Materials.

For the sake of simplicity it was intended to use plaster of Paris alone as a substratum. But owing to its hardness, it proved difficult to remove from glass petri-dishes after use, even when soaked in water for some days. Therefore a quantity of commercial kaolin was added to the plaster before watering. A standard mixture was kept for use consisting of three weights of plaster of Paris to one weight of kaolin. To 100 gms. of this mixture 64 ccs. of water were added in bulk and rapidly mixed so that it could be poured into the glass dishes used for tests while it was still very fluid. The petri-dishes had 5.5 cm. inside diameter and were 3.5 cms. deep. Plaster was poured in to a depth of 1.0 cm. and put to dry in a hot room at 28°C. for 72 hours. At the end of this time the plaster had completely dried, retaining only that water required for the di-hydration of the calcium hemihydrate. Drying could also be effected overnight in an oven at 50°C. Two small blocks of the plaster (14 and 23 cc.) were made for estimations of porosity (Rep. Build. Res. Board). The amount of water absorbed after evacuation indicated porosities of 56 per cent. and 54 per cent. volume respectively. If not required for immediate use, the plasters were stored at room temperature.

The insecticide used was Pyremist "I," kindly supplied by Messrs. Stafford Allen & Sons, London. This is a solution of pyrethrins in refined medium petroleum oil (Shell oil P31). Chemical estimations of pyrethrin I were carried out (in Dr. Tattersfield's Department at Rothamsted Experimental Station), and the original solution was suitably diluted for experiments.

Lanette wax SX (Harry, 1941) proved a useful emulsifying agent, and was used as a 1½ per cent. wt./vol. solution in distilled water.

Methods.

Various stages of the tick were used, and all were fully gorged with rabbit's blood 24 hours before being used for experiments. They are more resistant in this state than in an unfed condition.

For spraying a Potter tower was used (Potter, 1941) with an air pressure of 39 cm. mercury (7½ lb. sq. in.), and a gap of 2.5 cms. between the turntable and the base of the tower. For each spraying a weighed coverglass was placed beside the plaster

substratum, and the deposit of insecticide on it was weighed on a torsion balance to give an assessment of the dose received by the plaster. Tests showed that the amount per unit area was somewhat less on the plaster than on a coverglass beside it, probably owing to turbulence effects. The difference factor was ascertained and used in the assessment of the actual dose on the plaster substratum.

After spraying, the wall of each petri-dish was carefully wiped free of insecticide, and ten minutes were allowed to elapse before the ticks were released on to the sprayed surfaces. The dishes were kept in a warm room at 28 C. and 50 per cent. relative humidity. In most cases final mortality could be assessed within four days after spraying. Usually each plaster was used only once.

Dosage and Concentration of Pyrethrum.

The dosage-mortality relationship was first investigated by releasing ticks on to a single series of plaster blocks sprayed previously with increasing doses. Such a method had given satisfactory results when the substratum was filter-paper (Robinson, 1942b), but with plaster as the substratum, the dosage-mortality data from a single series were so erratic that no safe interpretation could be based upon them. The experimental procedure and the plaster were standardised, and it is possible that the degree of activity of the ticks in the different dishes varied greatly enough to cause large differences in the uptake of insecticide through the legs. (A negligible amount enters by way of the general body cuticle.) The stock of ticks had recently proved reasonably homogeneous (Robinson, 1942c), and the errors could not be ascribed to normal variation of the population. The practical disadvantage of these errors in the tests was that no repetition of results was possible. Of two substrata sprayed with the same deposit of insecticide, one might give a very low mortality, the other a very high one: actual cases occurred where the mortalities were 0 and 100 per cent. respectively on apparently similar blocks. Such blocks were tested for porosity after toxicity experiments and found to be uniform within the limits of the determination ($2\frac{1}{2}$ per cent. difference for 55 per cent. porosity). Some undetected character of the surface may have been the variable factor in addition to activity of the ticks. By this method then no safe prediction could be made about

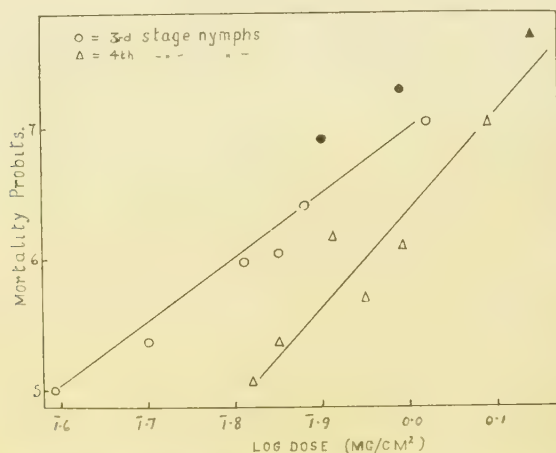


Fig. 1. Log. dose-probit lines showing the susceptibility of nymphal stages of *O. montana* to Pyrethrum "L" sprayed on to plaster. The regression lines were placed by eye, and the black points indicate 100 per cent. mortality. See Table I.

the effect which a certain dose would be likely to have. The difficulty was overcome by doing multiple sprayings at various dosages and averaging the mortalities due to a given deposit. The average effect of a dose applied on a sample of, say, five plasters was found to be reasonably consistent from sample to sample, though the variation within each sample might be considerable. In this way dosage could be satisfactorily decided upon before experiment.

The response of third and fourth stage nymphs of the tick to Pyremist "L" containing 0.41 per cent. pyrethrin I is shown in Table I. In fig. 1, the data are shown graphically by the method of Bliss (1935) and the regression lines have been placed by eye.

TABLE I.

The Susceptibility of 3rd and 4th Stage Nymphs of Ornithodoros moubata to a Film of Pyremist "L" (0.41 per cent. Pyrethrin I in Shell Oil P31) on Plaster. See Fig. 1.

Number of dishes	Ticks/dish	Dose per plaster, mg./cm. ²	Average % mortality
<i>3rd stage nymphs</i>			
5	20	0.39	50
6	10	0.50	65
5	20	0.65	84
10	10	0.70	85
10	15		
4	10	0.76	92
6	20	0.79	100
5	10	0.98	100
10	15	1.05	98
<i>4th stage nymphs</i>			
5	15	0.66	52
8	15	0.70	63
4	10	0.82	88
10	15	0.90	74
9	10	0.97	87
5	15		
4	10	1.22	98
5	15	1.38	100

As the engorged female is the most resistant active stage of this tick (Robinson, 1942 c), its resistance to the pyrethrum film was tested. The results are shown in Table 1A.

TABLE IA.

The Susceptibility of Females of Ornithodoros moubata to a Film of Pyremist "L" (0.41% Pyrethrin I) on Plaster.

No. of dishes	Ticks/dish	Dose per plaster mg./cm. ²	Average % mortality
1	5	0.59	60
2	5	0.70	60
2	5	0.95	50
2	5	1.16	70
2	5	1.35	90
1	5	1.96	100
1	5	2.15	100

A comparison of Tables I and IA shows the median lethal doses of Pyremist "L" on plaster for 3rd stage nymphs, 4th stage nymphs and females of the tick to be approximately 0.4, 0.6 and 0.8 mg./cm.² respectively.

The data for the two regression lines in Table I were obtained by experiments on 1,000-2,000 ticks. So much time and labour is needed to produce such numbers that in the subsequent tests comparisons were made at only three dosages administered, to 3rd or 4th stage nymphs as convenient.

It was desired to find out whether any advantage accrued from diluting a given quantity of pyrethrum solution before applying it to plaster. In all cases the diluted solution proved less toxic as seen in Table II.

TABLE II.

Toxicity to Ornithodoros moubata of two Concentrations of Pyrethrum-oil Solution sprayed on to Plaster.

No. of dishes	No. of ticks per dish	Concentration of pyrethrin I	Dose of fluid mg./cm. ²	Average % mortality
5	20 3rd stage nymphs	0.410	0.39	50
5	20 3rd stage nymphs	0.205	0.97	29
5	15 4th stage nymphs	0.410	0.66	52
5	15 4th stage nymphs	0.205	1.42	35
5	15 4th stage nymphs	0.410	0.93	76
5	15 4th stage nymphs	0.205	1.97	55

It is clear that as a film on plaster a given weight of pyrethrins is more toxic in concentrated form than when medium petroleum oil is added to it. This was the expected result, but such tests were deemed necessary, because when pyrethrum sprays had been tested against first stage nymphs on a substratum of filter paper (Robinson, 1942b) the more dilute sprays had proved more effective than the more concentrated sprays at the lower dosages.

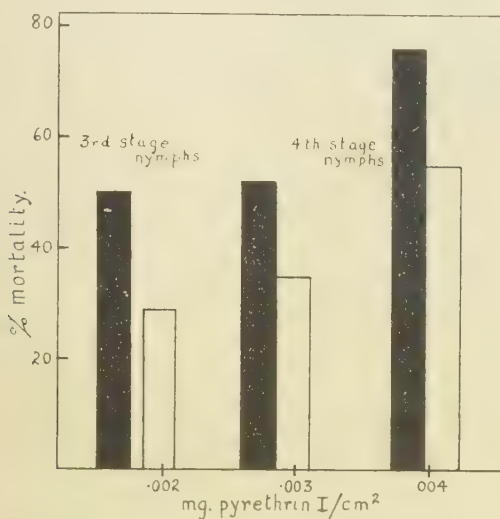


Fig. 2. Graphical picture of the data in Table II, showing how toxicity of a given quantity of pyrethrum diminishes with dilution. The nymphs absorbed the poison by walking over sprayed plaster. Black columns: pyrethrin I at 0.41 per cent. White columns: pyrethrin I at 0.205 per cent.

The Diluent.

The nature of the diluent is an important factor deciding how effective the active principle of an insecticide shall be (Robinson, 1942a & c), and tests were done to see what improvements could be made on the white oil diluent of the pyrethrum solution used. Unless otherwise stated, the results should be taken as applying only to action on a plaster substratum and not to direct spraying of ticks.

1. Oils.

The effect of partial replacement of the white oil diluent with a lighter fraction was investigated. A quarter of the P31 oil (Redwood I at 20°C., 141 seconds) was replaced with "odourless distillate" (Redwood I at 20°C., 32 seconds). Fuller specifications of these two oils are given in Robinson (1942a). This did not increase the toxicity very much as can be seen from Table III.

TABLE III.

The Effect of the Diluent on the Toxicity of Pyrethrum (0.3 per cent. Pyrethrin I) on Plaster to 3rd Stage Nymphs of Ornithodoros moubata.

Medium	No. of dishes	No. of ticks per dish	Deposit of insecticide mg./cm. ²	Average % mortality
P31	4	10	0.64	30
$\frac{3}{4}$ P31, $\frac{1}{4}$ odourless distillate	4	10	0.62	30
P31	5	10	0.75	52
$\frac{3}{4}$ P31, $\frac{1}{4}$ odourless distillate	5	10	0.67	60
P31	4	10	0.87	85
$\frac{3}{4}$ P31, $\frac{1}{4}$ odourless distillate	4	10	0.88	100

A further test was made on the light oil using a greater proportion as a diluent. From a pyrethrum-kerosene concentrate two solutions were made up with equal pyrethrin content, one of which was 84 per cent. Shell oil P31 and the other of which was 84 per cent. odourless distillate. The results of toxicity tests are seen in Table 4.

TABLE IV.
The Effect of the Diluent on the Toxicity of Pyrethrum (0.4 per cent. Pyrethrin I) on Plaster to 3rd Stage Nymphs of Ornithodoros moubata.

Medium	No. of dishes	No. of ticks per dish	Deposit of insecticide mg./cm. ²	Average % mortality
84% P31	4	10	0.40	67
84% odourless distillate ...	4	10	0.38	0
84% P31	7	15	0.36	36
84% odourless distillate ...	7	15	0.35	0
84% P31	6	20	0.59	46
84% odourless distillate ...	6	20	0.59	10

The apparent promise shown by the odourless distillate at 25 per cent. (Table III) was not fulfilled at 84 per cent., at which concentration it proved far inferior to the medium oil P31 as a carrier of pyrethrum in a film deposited on plaster. These results are the reverse of direct-spray experiments on ticks with two similar solutions: 0.075 mg. cm.² of a solution of 0.1 per cent. Pyrethrin I was administered as a direct spray to two lots of 50 3rd stage nymphs. One solution was 96 per cent. medium Shell oil P31 and gave a mortality of 28 per cent. The other solution was 96 per cent. odourless distillate and gave a mortality of 92 per cent.

2. The Use of Emulsions.

The emulsion used consisted of one volume of Pyremist "L" shaken with two volumes of 1½ per cent. aqueous solution of Lanette wax SX (Harry, 1941). From Table V and fig. 3 it can be seen that a given deposit of Pyremist "L" is more effective if it has been applied as an emulsion.

TABLE V.
Toxicity to Ornithodoros moubata of Pyremist "L" (0.273 per cent. Pyrethrin I) applied on Plaster in Oil and as an Emulsion.

No. of dishes	No. of ticks per dish	Medium	Deposit of oil mg./cm. ²	Average % mortality
6	20 3rd stage nymphs...	Pyremist "L"	0.64	84
6	20 3rd stage nymphs...	Emulsion	0.64	100
4	20 3rd stage nymphs...	Pyremist "L"	0.84	40
4	20 3rd stage nymphs...	Emulsion	0.69	54
5	15 3rd stage nymphs...	Pyremist "L"	0.92	60
5	15 3rd stage nymphs...	Emulsion	0.94	100



Fig. 3. Graphical picture of the data in Table V, showing how the toxicity of a given quantity of pyrethrum increases when it is emulsified with "Lanette wax SX" solution. Each pair of columns represent the results of a double series of tests comparing the pyrethrum-oil medium with the pyrethrum-oil-in-water emulsion. *O. moubata* absorbed the poison by walking over sprayed plaster. Black columns: Pyremist emulsion. White columns: Pyremist.

Another advantage of applying an oily insecticide in the form of an emulsion is the increased deposit obtained for a given amount of insecticide used. An emulsion produces no noticeable mist which is so characteristic of medium oil sprays. The escape of these finer particles of oil from the desired target is thus largely prevented.

3. Irritants.

It was mentioned above (p. 270) that the degree of activity of the ticks might have accounted for anomalous results in some of the experiments. It seemed highly probable that activity is at any rate one of the important factors controlling the size of the dose which a tick absorbs from the plaster. Consequently it was thought that the addition of an irritant substance to a pyrethrum spray would improve its efficiency. Certain compounds of phenol had proved to have irritating properties. These compounds are volatile solids or liquids which have in high concentrations a powerful fumigant action on the tick. At lower concentrations the vapours exert an excitatory action, and this was easily attained by releasing the ticks on to plaster sprayed with an oil solution of the substances. The plasters were put without covers into a ventilated constant temperature room at 28°C. and about 50 per cent. humidity.

The method was to compare the toxicity of a series of equal deposits on plaster of pyrethrum solution, phenol solution and a mixture of equal parts of these two. The results are shown in Table VI and fig. 4.

In all three series of experiments it can be seen that the dilution of Pyremist "L" (medium 1) with the non-toxic 4-chlor-2-methyl-phenol solution (medium 4) decreases the toxicity of the mixture (medium 2) only very slightly compared with what might be expected (medium 3). In other words the presence of the 4-chlor-2-methyl-phenol improves the action of Pyremist "L" acting on a substratum.

TABLE VI.

Toxicity to Ornithodoros moubata of Pyremist "L" (0.41 per cent. Pyrethrin I), 10 per cent. 4-chlor-2-methyl-phenol in Oil and a Mixture of equal Parts of these. Sprays were applied to Plaster Substrata. Toxicity of half the Concentration of Pyremist "L" (0.205 per cent. Py. I) is included for Comparison.

No. of dishes	No. of ticks per dish	Medium	Dose of fluid mg./cm. ²	Average % mortality
6	10 3rd stage nymphs ...	1. Pyremist "L" (0.41% Py. I)	0.68	98
6	10 3rd stage nymphs ...	2. Pyremist-phenol mixture	0.71	87
6	10 3rd stage nymphs ...	3. Pyremist "L" (0.205% Py. I)	0.73	52
6	10 3rd stage nymphs ...	4. Phenol solution	0.77	0
8	15 4th stage nymphs ...	1. Pyremist "L" (0.41% Py. I)	0.67	71
8	15 4th stage nymphs ...	2. Pyremist-phenol mixture	0.70	63
8	15 4th stage nymphs ...	3. Pyremist "L" (0.205% Py. I)	0.67	15
8	15 4th stage nymphs ...	4. Phenol solution	0.73	0
5	15 4th stage nymphs ...	1. Pyremist "L" (0.41% Py. I)	0.93	76
5	15 4th stage nymphs ...	2. Pyremist-phenol mixture	0.90	74
5	15 4th stage nymphs ...	3. Pyremist "L" (0.205% Py. I)	0.98	45
5	15 4th stage nymphs ...	4. Phenol solution	1.10	0

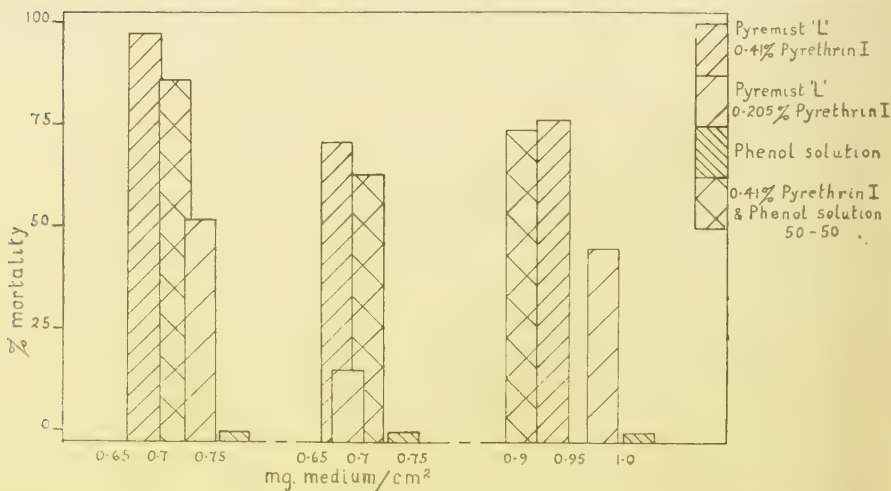


Fig. 4. Graphical picture of the data in Table VI showing how 4-chlor-2-methyl-phenol improves the toxicity of a pyrethrum film on plaster, although it is non-toxic in itself. *O. moubata* absorbed the poison by walking over sprayed plaster.

A similar series of solutions used as direct sprays on the ticks showed no remarkable activity of the pyremist-phenol mixture. A dose of 0.075 mg. cm.² of 0.1 per cent. Pyrethrin I in Shell oil P31 killed 44 out of 50 3rd stage nymphs, whereas a similar dose of pyrethrum diluted with phenol solution killed only 9 out of 50 ticks. Here the phenol solution acted purely as a diluent.

These experiments show that the phenol does not behave as an activator of the pyrethrum. As outlined above, its improvement of the pyrethrum film on the substratum lies in the excitatory effect of its vapour on the ticks. So long as the vapour comes off the substratum, the increased activity of the ticks presumably results in their increased uptake of pyrethrum.

As an addition to a spray used in the field, the phenol solution might have a useful initial effect, but it should be borne in mind that its vapour would tend to disperse rather quickly, according to its concentration and the character of the sprayed surface.

Summary.

Pyrethrum-oil films were tested in various forms on plaster substrata against the tick, *Ornithodoros moubata*. The insecticide was most effective if applied:—

1. Concentrated rather than dilute.
2. In a medium rather than a light petroleum oil.
3. As an emulsion in Lanette Wax Solution rather than in oil alone.
4. With an irritant (such as 4-chlor-2-methyl-phenol) present in the solution.

Acknowledgments.

My thanks are due to Professor P. A. Buxton, F.R.S., in whose department the work was done, and to Dr. F. Tattersfield of Rothamsted Experimental Station where samples of Pyremist "L" were analysed.

References.

- BLISS, C. I. (1935). The calculation of the dosage-mortality curve.—Ann. appl. Biol., **22**, p. 134.
- HARRY, R. G. (1941). Modern Cosmeticology. London.
- POTTER, C. (1941). A Laboratory Spraying Apparatus and Technique for investigating the Action of Contact Insecticides.—Ann. appl. Biol., **28**, p. 142.
- REPORT OF THE BUILDING RESEARCH BOARD (1937). H.M. Stationery Office, London.
- ROBINSON, G. G. (1942 a). The penetration of pyrethrum through the cuticle of the tick, *Ornithodoros moubata* Murray.—Parasitology, **34**, p. 113.
- (1942b). The quantitative interaction of spray fluid and active principle in determining the toxicity of a pyrethrum preparation to the Argasid tick, *Ornithodoros moubata* Murray.—Ann. appl. Biol., **29** p. 290.
- (1942c). The relative toxicity of pyrethrum and rotenone in oil to the Argasid tick, *Ornithodoros moubata* Murray.—Bull. ent. Res., **33**, p. 273.

THE CULICINE MOSQUITOS OF ERITREA.

By D. J. LEWIS,

Entomologist, Sudan Medical Service.

A survey of the distribution of *Aedes aegypti* and other Culicine mosquitos was made during the dry season of 1942, between 31st March and 15th May. The position of Eritrea gives it a particular interest in relation to the possible spread of yellow fever from Africa to the East. In the west it borders on the Anglo-Egyptian Sudan, in parts of which yellow fever is endemic, and it has a Red Sea coast line of some 600 miles, near the centre of which is the port of Massawa. The Culicines hitherto found include six that are known to be potential vectors of yellow fever.

The topography and climate of Eritrea have been described by Lega, Raffaele and Canalis (1937). The country may be divided into four areas, the eastern and western plains, the mountain slopes and the plateau. The latter, on which lie several of the towns, is from about 1,900 to 2,500 metres (some 6,200 to 8,200 feet) above sea level.

The Species of Culicines.

Zavattari (1930) recorded the names of six Culicines from Eritrea, some of which had been found previously by Franchini (1925, 1928). Edwards (1941) recorded *Culex theileri*. Recent collections have increased the number of known species and other forms to 28, and it is likely that further work, during the rainy season, would reveal the existence of many others.

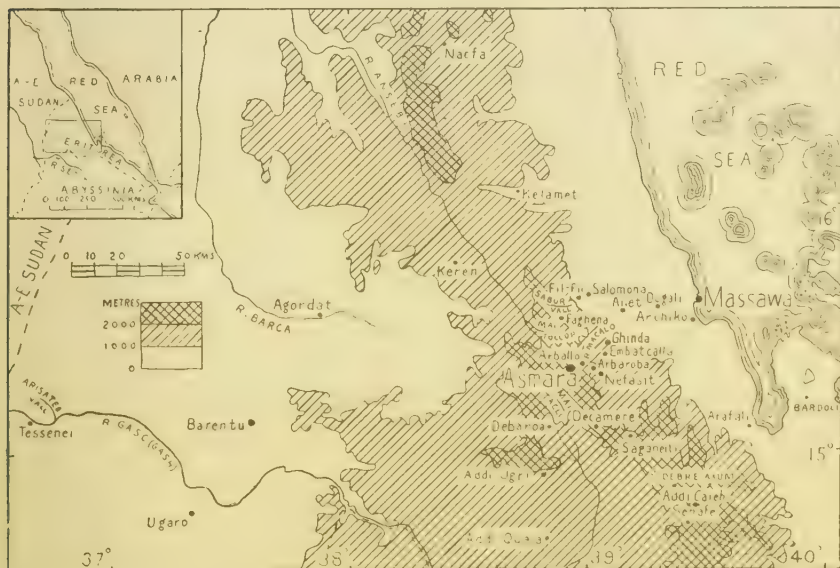


Fig. 1. Map showing the position of places mentioned in the text.

Records of localities, except where names of collectors are given, were made by the writer. Where the distribution of a species is not shown in the text, it appears in the table. Names of places are spelt as in the *Guida dell'Africa Orientale Italiana* (Milan, 1938, Consoc. Turistica Italiana) with the exception that accents are omitted, "ch" is changed to "k", and "u", when a consonant, to "w".

Uranotaenia mashonaensis, Theo.

Ghinda (*de Burca*) 30.viii.42, one larva in river seepage with végétation.

Theobaldia (Allotheobaldia) longiareolata, Macq.

With regard to the variation in the colouring of the abdominal tergites described by Edwards (*loc. cit.*), five specimens, from Asmara, Senafe, and Nacfa, were examined. All have numerous pale scales, except one from Asmara which has some dark scales and a median pale stripe. This species was never seen to bite man, even at Nacfa where its larvae were abundant. Specimens have occasionally been found in aircraft arriving in the Sudan from Asmara. It occurs in the Barca-Setit area (*G. Franchini*) and at places shown in the table. It usually bred in old oil drums containing water, often with *Culex laticinctus* or *C. fatigans*, and sometimes in ditches and pools.

Taeniorhynchus (Coquillettidia) sp.

Zavattari records *T. aurites*, Theo., from Addi Ugri, but it is not certain if the male terminalia, which distinguish this species from *T. chrysosoma*, were examined.

Taeniorhynchus (Mansonioides) uniformis, Theo.

Barentu (*Zavattari*).

Aëdes (Mucidus) scatophagoides, Theo.

Agordat (*de Burca*).

Aëdes (Ochlerotatus) caballus, Theo.

A larva obtained by Dr. L. Mara at Arafili may belong to this species, the larva of which has not been described. From Hopkins's (1936) key it would appear to be *A. caspius*. Adults of *A. caballus* were obtained at Bardoli in a mosquito net out of doors by Hussein Eff. Abd er Rahman.

Aëdes (Stegomyia) aegypti, L.

This species occurs in the Barca-Setit area (*Franchini*), at Keren and Agordat (common, *Zavattari*), and at other localities shown in the table. At each place above 1,700 metres, except Debre Axum, Debaroa, Mai Tacli, Faghena and Mai Taccor, 15 houses (a total of 135) were examined for larvae of *A. aegypti*. Although none was found, domestic breeding places were plentiful; much water was stored in drums, and larvae of species of *Culex* were common or abundant. The highest point at which *A. aegypti* was found was 1,648 metres above sea level. The altitude limit in the dry season in Eritrea is apparently between 1,650 and 1,980 metres (about 5,400 and 6,500 feet), but the exact limit is not known because there are few towns in this zone.

In the dry season this species tends to be common in towns on the eastern escarpment. At Nefasit and Embatcalla, before control was started, ten houses were examined in each place and larvae of *A. aegypti* were found in four and eight respectively.

Aëdes aegypti var. *queenslandensis*, Theo.

The pale colouring of this variety is more pronounced in the female than the male. Adults were seen biting by day in a dhow at Massawa. The variety breeds in domestic water vessels, wooden tanks and metal drums in dhows. At Archiko, before control measures were started, larvae were found in all of 14 houses examined.

Aëdes (Stegomyia) simpsoni var. *lilii*, Theo.

Nefasit (one female in drum, 9.v.42).

Aëdes (Stegomyia) luteocephalus, Newst.

Nefasit (larva in drum, 9.v.42).

Aëdes (Stegomyia) vittatus, Bigot.

Arasiteb, Tessenei and Ugaro (*de Burca*). Captain de Burca has informed me that this species breeds in great numbers on the eastern slopes in July.

Aëdes (Aëdimorphus) eritreae, Lewis.

The female bites readily by day (*Lewis*, 1942). Larvae were found at Debre Axum, c. 1,980 metres, in a large rock pool formed during road construction.

Culex (Lutzia) tigripes, Grandpré.

With regard to the variation in the colouring of the abdomen described by Edwards (*l. c.*), two specimens from Ghinda were examined. One resembled variation no. 2 and the other no. 3. Larvae were found in pools in streams, sometimes with *C. duttoni*, and in drums of water.

Culex (Neoculex) salisburyensis, Theo.

Larvae were found in pools in streams.

Culex (Culex) poicilipes, Theo.

Tessenei (*Mara*).

Culex (Culex) ethiopicus, Edw.

Western Eritrea (over 2,100 metres) and Agordat (x.42, *de Burca*). Larvae were obtained in a pool in a hill stream and in a swamp.

Culex (Culex) annulioris, Theo.

Saganeiti (ix.42, *de Burca*) ; Addi Ugri, Fil-Fil. The species breeds in streams.

Culex sp.

Some larvae from Massawa resemble *C. sitiens*, Wied., in several respects, and, when adults can be bred, they may prove to belong to a variety of this species.

Culex (Culex) duttoni, Theo.

Larvae are usually found in drums and sometimes in pools in streams.

Culex (Culex) theileri, Theo.

Although many thousands of larvae were found in a stream near houses at Debaroa, the occupants did not complain of being bitten. Larvae occur in weedy streams, sometimes with *Anopheles cinereus*. The species occurs at Asmara (*G. Raffaele*, Edwards, *l. c.*) and at places shown in the table.

Culex (Culex) univittatus, Theo.

Agordat, Barentu and Keren (*Zavattari*); Addi Caieh; Ghinda (*de Burca*).

Culex (Culex) simpsoni, Theo.

Addi Caieh, pool in stream.

Culex (Culex) sinaiticus, Kirkpatrick.

In the larvae head-seta B is often double. Larvae were found in streams (often with *Anopheles d'thali*) and in a well at Kelamet.

Culex (Culex) laticinctus, Edw.

Near Debre Axum a living male was seen being sucked by a species of STOMOXYDINAE. At Nacfa the writer spent two nights within a few yards of a prolific breeding place of *C. laticinctus*, *T. longiareolata* and *Anopheles cinereus* without noticing any bites. *C. laticinctus* breeds in drums, wells, tanks and pools in streams.

Culex (Culex) pipiens, L.

Barca-Setit area (*Franchini*); Asmara (*Raffaele*, Edwards, *l. c.*); Nefasit and Addi Caieh.

Culex (Culex) fatigans, Wied.

In many Eritrean larvae of this species, head-seta *f* has more than two branches, which is the number given by Hopkins (1936) as a character distinguishing this species from *C. pipiens*. In three pelts (identified by examination of the corresponding male terminalia) from Massawa and Asmara the number of branches varied from 3 to 5. Seta *e* had 2 or 3 branches, the siphonal index was from 3.4 to 3.7 and the pecten had from 7 to 11 teeth.

C. pygmaeus, N.-L., recorded from Keren by *Zavattari*, may be a synonym of *C. fatigans* or *C. sinaiticus* (Edwards, *l. c.*).

C. fatigans was a particularly troublesome biter at Asmara and Massawa. Larvae were found in drums, street drains, a water tank, in a dhow, and once in a dirty well.

Culex (Culex) trifilatus, Edw.

Larvae were found in drums.

Culex (Culex) andersoni subsp. *abyssinicus*, Edw.

The larva can easily be recognised by the presence of a chitinous tooth, not unlike that of *C. duttoni*, on the dorsal side of the siphon near its apex. Larvae occur in drums, cement tanks and pools in streams.

Culex (Culex) decens, Theo.

Ghinda and R. Anseba valley near Keren, in pools and a well respectively.

Composition and Distribution of the Mosquito Fauna.

Owing to the situation of Eritrea, on the north-east coast of Africa and at the northern end of the east African Mountains, its mosquito fauna includes species whose range covers many of the faunal areas of Africa. Edwards (*l. c.*), discussing Chapin's North-East Africa faunal Province which includes Eritrea. Referring principally to the mosquitoes of Abyssinia, British Somaliland, northern Kenya and south-west Arabia, he distinguishes two main groups of mosquitoes, those of the

highlands and those of the Somali Arid District, and points out that only a few true Ethiopian species are known. The Culicines of Eritrea include many true Ethiopian forms and may be grouped as follows, according to their general distribution outside Eritrea.

Main area of Distribution.	Species, subspecies and varieties.
Palaeartic Region	<i>T. longiareolata</i> , <i>A. caballus</i> , <i>C. sinaiticus</i> , <i>C. laticinctus</i> , <i>C. pipiens</i> , <i>C. theileri</i> (the last two occur also in large areas of Africa).
Ethiopian Region.	
Eastern and Southern Province...	<i>U. mashonaensis</i> , <i>C. salishuriensis</i> , <i>C. trifilatus</i> .
Abyssinian Highland District ...	<i>A. eritreae</i> , <i>C. andersoni</i> subsp. <i>abyssinicus</i> .
Ethiopian Region, and, in the case of four forms, Palaeartic or Oriental Regions	15 of the remainder.
Ethiopian and Oriental Coastal Areas	<i>A. aegypti</i> var. <i>queenslandensis</i> , <i>C. sp. (sitiens</i> var ?).

With regard to distribution inside Eritrea, at least some species, as shown in the table, fall into groups according to their dry-season prevalence in one or more of the principal areas of the country.

The Palaeartic and East African forms are found chiefly at the higher altitudes, and many of the typical Ethiopian forms occur in the plains and on the lower hill slopes.

The greatest vertical range is attained by *C. fatigans* which occurs at sea level and at 2,390 metres. It is seldom abundant except in towns with street drains.

About half the towns lie above the dry-season range of *A. aegypti*. Domestic breeding places, utilised by this or other species, are numerous in many parts of the country. The supply of water is often limited and much is stored in old oil drums, great numbers of which became available during the Abyssinian War of 1935 to 1937. Many houses, even small dwellings, contain several large drums, and in one small garden as many as 125 vessels of water were seen, comprising oil drums, carbide drums and large wine flasks.

Importance and Control.

The known potential vectors of yellow fever are *Aedes aegypti* and its variety *queenslandensis*, *A. vittatus*, *Culex fatigans*, *A. simpsoni* var. *lillii* and *A. lateralis*. On several occasions in recent years *C. fatigans* has been found in aircraft arriving in the Sudan from Asmara.

At Massawa the control of *A. aegypti* var. *queenslandensis* is carried out as a precaution against yellow fever and dengue.

The only Culicines seen to bite man in the dry season were *A. aegypti* and var. *queenslandensis*, *A. eritreae*, *A. caballus* and *C. fatigans*. Blood-gorged *C. pipiens* have been found in rooms. There is some evidence that *T. longiareolata*, *C. theileri* and *C. laticinctus* seldom if ever bite people in Eritrea.

Species, the larvae of which are commonly found in water containers in or near houses, are *T. longiareolata*, *A. aegypti* and var. *queenslandensis*, *C. tigripes*, *C. duttoni*, *C. laticinctus*, *C. fatigans*, *C. trifilatus* and *C. andersoni* subsp. *abyssinicus*.

TABLE I.

The known Distribution of certain Species in the Dry Season.

Area	Plains	Eastern and western Slopes	Plateau
1	Massawa	10	Arbalo
	Arbico	c. 100	Dogali
	257	Ailet	585
	Tessenet	615	Agordat
	c. 800	Salomona	c. 820
	820	El-Fil	c. 850
	850	Sabur Valley	890
	890	Ghinda	980
	980	Barentu	980
	980	Kalamet	1,273
	1,273	Embatcalla	1,350
	1,350	R. Anseba	1,392
	1,392	Keren	c. 1,600
	c. 1,600	R. Macalo	1,648
	1,648	Nefasi	1,750
	1,750	Xarta	1,930
	1,930	Debaroa	c. 1,980
	c. 1,980	Debre Axum	1,980
	1,980	Addi Ugr	c. 1,988
	c. 1,988	Mai Tachi	c. 2,017
	c. 2,017	Faghena	2,054
	2,054	Addi Quala	2,060
	2,060	Decamere	2,064
	2,064	Arbaroba	c. 2,150
	c. 2,150	Arbalo	2,203
	2,203	Saenenti	c. 2,340
	c. 2,340	Mai Taccor	c. 2,347
	c. 2,347	Asmara	c. 2,390
	c. 2,390	Addi Caieh	2,480
	2,480	Senale	

Altitude in metres

<i>C. salisburyensis</i> ...	
<i>C. andersoni abyssinicus</i>	
<i>C. theileri</i>	
<i>T. longirostris</i>	
<i>T. fulvum</i>	
<i>T. tigris</i>	
<i>C. fulvipes</i>	
<i>C. trilineatus</i>	
<i>C. annulatus</i> and <i>orthopneustes</i>	
<i>A. aegypti</i>	
<i>C. sinaiticus</i>	
<i>A. aegypti queenslandensis</i>	
<i>C. sitiens</i> var ?	
<i>C. fulvipes</i>	

Control.

Control of *Aedes aegypti* was being carried out by the usual methods in most towns of the mountain slopes and plains. These methods also limit the breeding of *C. fatigans* to a great extent, but complete control of this species is difficult owing to the time necessary for inspecting the large number of possible breeding places in basements and underground drains.

On the plateau, owing to the high altitude and the fact that *C. fatigans*, the common domestic mosquito, is probably not an efficient vector of yellow fever (Davis, 1933), it is doubtful if mosquito control is necessary as a measure against this disease, except near aerodromes.

Biological control of mosquitos may be of value in places where much water is stored. *Gambusia affinis holbrooki* was introduced from the Sudan by the writer, and stocks were established in two permanent streams, the Mai Taccor 15.5 kms. from Asmara on the Keren road, and a stream 18.5 kms. from Massawa on the Asmara road. Others were placed in artificial containers at Agordat, Asmara, Barentu, Ghinda, Keren, Massawa, Nacfa, Senafe and Tessenei.

Cyprinid fish about three inches long are common in many streams on the plateau and in the foothills and plains, but they have often been seen in company with mosquito larvae. They do not appear to attack *Gambusia*.

Acknowledgments.

I am very much indebted to Lieut.-Colonel R. H. Bland, R.A.M.C., and many other officers of the Administration, for providing facilities during this survey, and to Captain B. de Burca, I.M.S., for a number of collections. The names of others who kindly contributed specimens are mentioned in the text.

References.

- DAVIS, N. C. (1933). Transmission of yellow fever virus by *Culex fatigans* Wiedemann.—Ann. ent. Soc. Amer., **26**, pp. 491–495.
- EDWARDS, F. W. (1941). Mosquitoes of the Ethiopian Region III.—Culicine adults and pupae. British Museum (Natural History).
- FRANCHINI, G. (1925). Brevi note di entomologia sulla Somalia e sulla Eritrea.—Pathologica, **17**, pp. 494–495.
- (1928). Su di alcune specie di lanzare non ancora descritte nelle nostre colonie.—Arch. Ital. Sci. med. colon., **9**, pp. 458–459.
- HOPKINS, G. H. E. (1936). Mosquitoes of the Ethiopian Region I.—Larval bionomics of mosquitoes and taxonomy of Culicine larvae. British Museum (Natural History).
- LEGA, G., RAFFAELE, G. & CANALIS, A. (1937). Missione dell' Istituto di Malarologia nell' Africa Orientale Italiana.—Riv. Malariol., **16** pp. 325–387.
- LEWIS, D. J. (1942). A new species of *Aedes* (Dipt., Culicidae) from Eritrea.—Proc. R. ent. Soc. London, (B) **11**, pp. 165–166, 1 fig.
- ZAVATTARI, E. (1930). Gli artropodi ematofage della colonia Eritrea.—Relazioni degli studi compiuti nel Bassopiano Occidentale dell' Eritrea. Parma.

A NEW GENUS AND SPECIES OF MIRIDAE (BRYOCORINAE) FEEDING
ON *KHAYA GRANDIFOLIOLA* IN THE GOLD COAST (HEMIPTERA
HETEROPTERA).

By W. E. CHINA, M.A., F.R.E.S.

Amongst a collection of MIRIDAE made by Mr. H. E. Box in the Gold Coast, during his work on the insect pests of cacao plantations, is a series representing a new genus and species of BRYOCORINAE allied to *Sahlbergella*, Hagl. These specimens were submitted to me by the Imperial Institute of Entomology and are herewith described.

Boxia, gen. nov.*

Head very short, seen from above more than twice as broad including eyes as long in middle, transverse, seen from side about as long as high; frons angularly rounded apically between antennae, without the two tubercles present in *Sahlbergella*; vertex with minute depressed scale-like pubescence, its base between the eyes with two oblique laevigate scars but without the two impressions present in *Sahlbergella*; clypeus vertical, only moderately prominent, well delimited from the frons. *Lora* prominently rounded; eyes prominent laterally but not substylate as in *Sahlbergella*, extending posteriorly quite to basal margin of head and laterally well beyond anterior lateral margins of pronotum, facets smaller and less prominent than in *Sahlbergella*, giving a smoother, less granulate appearance; rostrum extending to middle coxae, the basal segment thickened, extending beyond bucculae but not reaching the base of head; antennae very finely pubescent, inserted midway between apex of frons and apical margin of eye; the first segment very short, about as long as diameter of an eye, distinctly thickened, remaining segments relatively slender, without the swellings and thickenings found in *Sahlbergella*, the second segment a little longer than the third and fourth together, the fourth fusiform, the third slightly thickened. *Pronotum* much less convex than in *Sahlbergella*, densely reticulately punctate, except for anterior collar and calli, without the tubercular swellings present in *Sahlbergella*; anterior collar extending posteriorly in a triangular area between the calli, its anterior margin with an angular indentation; anterior lateral angles of pronotum raised in an arcuate swelling. *Scutellum* triangular, convexly swollen in middle but not apically, and not produced backwards in a swollen pointed lobe as it is in *Sahlbergella*, surface densely reticulately punctate and, as in pronotum, without tubercles. *Hemelytra* longer than the abdomen, finely shagreened; costal margin dilated beyond apex of scutellum; cuneus short and broad, a little longer than broad at base; membrane with a single basal cell, its delimiting vein parallel with the posterior margin of the corium and not forming a sharp angle as in *Sahlbergella*. *Hind wing* without hamus. *Legs* simple, the tibiae much thicker than tarsi and distinctly thicker relatively than in *Sahlbergella*; covered with a dense short pubescence but without spines; first hind tarsal segment about three-quarters the length of the second and third together and relatively distinctly longer than in *Sahlbergella*; the last tarsal segment as in *Sahlbergella*, not distinctly widened towards apex as in most BRYOCORINAE; arolia large, divergent, broad at base, narrowing towards apex, closely adpressed to claws at base, extending to apices of claws. *Abdominal segments* with posterior lateral angles prominent as in *Sahlbergella*.

*Dedicated to the collector, Mr. H. E. Box.

Genotype :—*Boxia khayae*, sp. nov.

Closely allied to *Sahlbergella* but differing particularly in the slender simple antennae, non-stylate eyes, non-tuberculate pronotum, broader anterior collar in middle, smaller, simply convex, scutellum, and membrane cell non-angular. Runs down in Poppius' key to African BRYOCORINAE to *Monalocoropsis*, from which it is at once distinguished by the strongly punctate pronotum and scutellum and rough-surfaced hemielytra.



Fig. 1. *Boxia khayae*, gen. et sp. nov.

***Boxia khayae*, sp. nov. (figs. 1 and 2).**

Colour ♂ and ♀. Fulvous yellow, more or less mottled with black, this mottling very variable, sometimes very dense so that the posterior two-thirds of pronotum and apical three-quarters of cuneus are black. Such specimens have a broad black transverse band just about the apical margin of corium. Eyes black, a blackish suffusion over frons between antennae, and a double black spot in middle of basal margin of head; basal segment of antennae fulvous, minutely speckled with red, second segment shading from fulvous at extreme base to dark brown, its apex with a distinct fulvous ring; third and fourth segments black, each with its apex fulvous; rostrum black. Legs fulvous, the femora with a broad black subapical ring containing two brightfulvous spots; tibiae fulvous with the base and apex black and a broad median annulation dark brown; tarsi black. Ventral surface fulvous, a broad black lateral margin to propleura, some black spots on acetabula, a dark brown smudge on middle of lateral margin of each segment of connexivum and a large black spot on each side of genital segment; ovipositor valves of female black. Venter more or less stippled with pale brown.

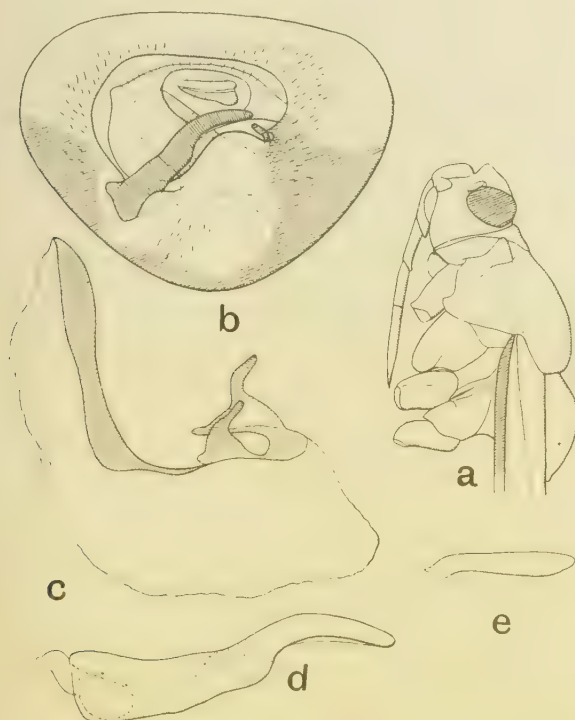


Fig. 2. *Boxia khayae*, gen. et sp. nov. *a*, lateral view of head and thorax; *b*, terminal view of male genital capsule (pygophor) showing parameres, aedeagus and anal segments *in situ*; *c*, aedeagus seen from side; *d*, left hand paramere (genital clasper); *e*, right hand paramere.

Structure ♀ (*). *Head* nearly three times as wide (including eyes) as long in middle (40 : 15), extending laterally well beyond anterior lateral angles of pronotum ; posteriorly with a very fine golden scale-like pubescence. Rostrum extending to middle coxae, relative lengths of segments 13 : 12 : 12 : 20 ; first antennal segment thickened about two-thirds as thick as long, second and third segments relatively slender ; third slightly thickened, both clothed with fine, dense, sub-erect pubescence ; fourth fusiform ; relative lengths of segments 9 : 54 : 34 : 24, the last segment one-sixth as wide in middle as long (4 : 24). *Pronotum* rather more than half as long in middle as wide across humeral angles (40 : 75) and a little more than half as wide across the anterior collar as long in middle (24 : 40) ; anterior collar indented in middle of anterior margin, lateral margins of pronotum slightly concavely emarginate ; the posterior lateral margins and posterior margin also shallowly emarginate ; anterior lateral angles on each side of collar and above calli raised in an arcuate rounded ridge ; anterior collar extending posteriorly in a V-shaped lobe between the calli, the latter bounded posteriorly by a pair of shining arcuate linear impressions ; surface of pronotum densely reticulately punctate. Scutellum equilaterally triangular, three-fourths as long as pronotum (30 : 40), convexly swollen in middle, punctuation same as pronotum, a short impressed line in middle of base, the extreme apex smooth and slightly raised in a triangular, pallid, button. *Hemicytra* extending distinctly beyond apex of abdomen, the costal cell narrow at base but widening suddenly at about level of middle of scutellum ; cuneus much shorter than in *Sahlbergella*, only one-fifth longer than wide at base (25 : 20) ; surface of clavus and corium finely shagreened, the apex of corium, and cuneus on basal half, with a fine dense scale-like pubescence visible only at high magnification ; membrane with a single parallel-sided cell and one longitudinal vein. *Legs* normal, the apices of hind femora slightly thickened, with a short, sparse, dark pubescence ; tibiae with a fine dense sub-erect dark pubescence.

Length : 8-10 mm., width across humeral angles 4-4.5 mm.

Structure ♂ similar to female but rather smaller. Male genitalia figured.

Length : 7 mm., width across humeral angles 3.5 mm.

Habitat :—W. AFRICA, Gold Coast, Tafo, 3 ♂♂, 2 ♀♀, on *Khaya grandifoliola*, March 1943 (H. E. Box).

*The male specimens are teneral immature and consequently somewhat shrivelled, so that I have selected the female for structural description in detail.

AN ACCOUNT OF *SCHISTOCERCA FLAVOFASCIATA* (DE GEER 1773) IN TRINIDAD (ORTHOPTERA : ACRIDIDAE).

By D. KEITH MCE. KEVAN, B.Sc., F.R.E.S.

Department of Entomology, Imperial College of Tropical Agriculture, Trinidad.

Introduction.

The genus *Schistocerca* is one of very great economic importance, since it includes the Desert locust of the Old World, *Schistocerca gregaria* (Forsk.) and the South American locust, *S. paranensis* (Burm.). It was therefore considered of value to study the life history of one of the solitary species living in Trinidad, and the present investigations were made during 1942 at the Imperial College of Tropical Agriculture at St. Augustine.

The climate of Trinidad is humid tropical. The annual rainfall over nineteen years at St. Augustine averaged 68.4 inches, but in the north-east of the Island the rainfall is over 100 inches per annum, falling to below 60 inches on the West coast. The rainy season usually begins about June, with a break in August or September, and lasts till the end of the year or the early part of January. November may be taken as one of the wettest months with a rainfall of about 11.5 inches (at St. Augustine), while more than half an inch is not usual for April. The humidity in November averages about 85 per cent. in the morning and 77 per cent. in the afternoon, but it is still high in April, being 75 per cent. and 64 per cent. for morning and afternoon respectively. The night humidities are even higher. The temperature remains practically constant throughout the year, averaging about 84°F. (29°C.) during the day, and 74°F. (23.3°C.) at night. The temperature may reach 95°F. (35°C.) during the day in the dry season, but it seldom falls as low as 65°F. (18.3°C.) at night.

The topography of the Island is uneven, there being three ranges of hills from west to east—the northern range, which rises to 3,085 feet at its highest point, and the central and southern ranges, which are much lower and rise more gradually.

The vegetation falls roughly into nine categories: tropical rain forest; cacao plantations; natural savannah; sugar cane plantations; coconut plantations; peasant cultivation (both permanent and shifting); mangrove swamps; reed swamps; and other types of vegetation. The largest area is covered by tropical rain forest (both natural and afforested), or cacao, while most of the remaining part is under sugar cane.

The writer would like to thank Mr. J. A. G. Rehn for his identification of *S. flavofasciata*, and for much useful information and advice; Dr. B. P. Uvarov for his helpful suggestions and encouragement; Dr. A. P. Gurney for confirming the identification of *S. pallens*; Dr. A. M. Adamson for allowing the writer to use material in the College collection; Mr. R. E. D. Baker, for identifying *Aspergillus* sp.; Dr. J. Liebermann and Dr. A. A. Ogloblin for official and other publications of the Ministerio de Agricultura de la Nación (Buenos Aires) and the New York Entomological Society for a copy of Bruner's (1906) paper.

Technique.

Material for experimental purposes was collected almost entirely from a small banana plantation behind the students' residence at the Imperial College, St. Augustine, where the species was found feeding on *Canavalia*, banana leaves, etc.

Specimens reared in captivity were not subjected to experimental variations of temperature and humidity, and an attempt was made to keep these two factors as near to those of the surrounding atmosphere as possible. The adults were kept in wire gauze cages open on all sides to the air, or in a glass tank with a wire gauze top—the latter being used in quarantining material brought from the field.

The bottoms of the containers were covered with a layer of about three inches of soil, packed not too tightly. The soil was not sterilised—a fact which, however, seemed to be of little consequence.

Isolated adults were kept in small hemispherical wire gauze meat-covers of about five inches (13 cm.) in diameter, and these were placed on boxes of packed earth to allow for oviposition. Nymphs were reared in similar cages (when crowded), but these were placed on glass trays instead of on earth.

When the nymphs were isolated, they were reared in containers made from storm-lantern chimneys covered with muslin at the top and placed on zinc trays.

The advantages of these two types of cage over glass jars, in addition to keeping the humidity normal by allowing free circulation of air, is that when food is placed in them, it is put in at the bottom so that the insects jump upwards *into* the cage instead of out of it.

The insects were fed entirely on *Canavalia ensiformis* except in food preference tests.

Eggs were usually allowed to hatch without being disturbed, and on the site of oviposition was put a small meat-cage into which the young nymphs crawled, usually on to the wire, so that the whole cage with its contents could be removed wherever desired by slipping a sheet of glass under the edge.

The Species of *Schistocerca* in Trinidad.

1. *S. paranensis* (Burmeister 1861).

The South American locust appears only on rare occasions, and has not been recorded from Trinidad since 1916 and has not done very serious damage since 1885 (Urich, 1915 ; 1916 a).

All the records of *S. paranensis* in Trinidad are from the west coastal extremities nearest to the South American mainland—Icacos, Cedros, and Cap de Ville on the southern peninsula ; Patos (recently ceded to Venezuela and nearer to that country than to Trinidad), Chacachacare, Monos and Gaspare, which are all islands off the northern peninsula ; and Carenage on the northern peninsula. The actual records of the occurrence of the species are as follows :—

1885, May–June : Observed by Kernahan at Icacos where eggs were laid and nymphs persisted for three months ; and also by Bulmer in November in large numbers at Carenage (Urich, *loc. cit.*).

1915, May 29–30 : Patos, a swarm destroying corn ; Chacachacare, large numbers ; Icacos and Cedros, large numbers of dead locusts washed ashore (Urich, *loc. cit.*).

1915, May 29–June 8 : Patos, Chacachacare, Monos (very few), while at Gaspare, Icacos, Chacachacare and Monos (less) large numbers of dead locusts were washed ashore (Freeman, 1915).

1915, November 3 : Patos, small swarm (Urich, 1916).

1916, June–July : Patos, June 10, large swarm ; further swarms July 16, 18, 24 ; Cap de Ville and Icacos, July 11—these specimens were unusual, being brought alive on floating reeds from the Orinoco ; Chacachacare, July 15 and 24, swarms (Urich, 1916 a). Lynch Arribalzaga (1918, p. 64) obtained specimens of the Venezuelan locust from Trinidad and referred them to a new species, *S. urichi*, but this has been shown to be a synonym of *S. paranensis* by Hebard (1923, p. 281).

2. *S. pallens* (Thunberg 1815).

This species has only been recorded in literature once from Trinidad (Bruner, 1906, p. 156) but it has been taken on numerous occasions, though it is by no means common as compared with the next species.

Some of the more recent records from the I.C.T.A. collection are given below :—

I.C.T.A. savannah, Oct. 1928, 1♀; Caroni (Sugar Estate), 13.v.34, 1♂, 1♀; St. Augustine, 27.ii.35, 1♀; Piarco savannah, 2.iii.35, 1♂; I.C.T.A., 27.i.37, 1♀; 23.x.41, 1♀; Patos, on *Panicum maximum*, Jacq., 7.v.39, 2♀♀; St. Augustine, banana plantation, on *Canavalia*, etc., 4.i.42, 1♀; 8.i.42, 2♂♂; St. Augustine, on Guatemala grass, 11.ii.42, 1♂; I.C.T.A. savannah, 2.ix.42, 1♀; Woodford Lodge, Chaguanas, Corn field, 1.x.42, 2♂♂, 1♀.

3. *S. flavofasciata* (De Geer 1773).

This species was described by De Geer (1773, p. 489) from Surinam under the name of *Acrydium flavofasciatum*, and Scudder (1899, p. 444) described the same species from Demerara as *Schistocerca aequalis* (for synonymy see Rehn, 1916, p. 304; Kirby, 1910, p. 456; and Liebermann 1939 a, p. 205).

S. flavofasciata has not been published as occurring in Trinidad, but several references have been made to this species under other names.

The *S. columbina* (Thunb.) given as a Trinidad insect by Bruner (1906, p. 156) is almost certainly this species, an opinion with which Mr. Rehn (*in litt.* 1942) concurs, while *S. praesignata*, Rehn, the name used by Urich (1915 a, p. 160) and Serre (1916) is a *nomen nudum* (Rehn, *in litt.* 1942).*

Schistocerca sp. (Anonymous, 1915) can also be taken with certainty to refer to this species.

4. *S. americana* (Drury 1770) and *S. similatrix* (Walker 1870).

Bruner (1906, p. 156), in his list of Trinidad Orthoptera, mentions these two species, but without the actual specimens no conclusion as to the validity of the records can be reached. Presumably the former species would be a form of *S. paranensis* and the latter, *S. flavofasciata*.

The Occurrence of *S. flavofasciata* in Trinidad.

S. flavofasciata is widely distributed in South America, and material in the Academy of Natural Sciences of Philadelphia collection shows the range to be the Guianas, Lower Amazonian Brazil, Venezuela and the Dutch Islands, Trinidad, Tobago and Grenada* (Rehn, *in litt.* 1942) the last two islands being new records from specimens sent from the I.C.T.A. collection. A male specimen from St. Vincent also seems to be this species, though it may be *S. columbina*. Liebermann (1939 a, p. 205) cites references to the species in Brazil, Paraguay, Bolivia and Argentina, and in the last-mentioned country Daguette (1939, p. 135) notes that it is suspected of having as a habitat the beds of *Arundo donax* in the provinces of Catamarca and Chaco.

In Trinidad, both nymphs and adults may be found at all times of the year, occurring commonly, though not abundantly, over the whole island at all altitudes,

* Rehn did not describe *S. praesignata* but apparently intended to do so. Urich sent some specimens to Rehn, who gave them the name *praesignata*, not thinking that Urich would publish the name.

† The specimen (from Grenada) submitted to Mr. Rehn, of the Academy of Natural Sciences of Philadelphia, was of small size and somewhat heavily pigmented. A subsequent visit to Grenada by the author showed that *S. flavofasciata* in that island tends to belong to a rather small, dark race.

wherever the vegetation is open enough. The species occurs in savannah country—possibly the true habitat—in sugar-cane fields and in fields of maize, in areas of peasant cultivation (both permanent and shifting), in forest clearings, and in grapefruit plantations. In coconut and banana plantations it attacks the trees as well as the ground flora, though it never does appreciable damage. The species has even been taken among young cacao buddings where there was no overhead shade except for young banana plants.

S. flavofasciata, however, does not occur in the forest, nor among mature cacao, which, in addition to forming a dense cover of its own, is shaded by Immortel trees (*Erythrina* spp.), plantations of which, when neglected, may become almost as dense as the rain forest itself.

The species does not readily come to light, but in St. Augustine, 28.iv.42, 1 ♂ and 26.iv.42 1 ♀ were taken at light; on other occasions only males were seen.

Feeding Habits.

The actual method of feeding is for the insect to hold the part of the food-plant to be consumed between the front tarsi, and a hole is eaten out of the edge of the leaf. Sometimes a small piece of the leaf is freed from the rest of the plant, and the insect devours it, holding it after the manner of a squirrel. The mid-ribs (particularly of grasses) are not usually eaten (*cf.* Ulrich, 1915 a, p. 160).

Both nymphs and adults are very general feeders, and among the food-plants of economic importance attacked in nature the following have been noticed:—Maize (*Zea mays*), sugar-cane (*Saccharum officinarum*), rice (*Oryza sativa*), elephant grass (*Pennisetum purpureum*), savannah grass (*Axonopus compressus*), guinea grass (*Panicum maximum*), Para grass (*Brachiaria mutica*), Guatemala grass (*Tripsacum laxum*), corn grass (*Manisuris exaltatus*), banana (*Musa paradisiaca*), coconut (*Cocos nucifera*), horse bean (*Canavalia ensiformis*), and more rarely garden Hibiscus (*Hibiscus rosa-sinensis*), yam (*Dioscorea batatas*) and cabbage (*Brassica oleracea*).

The species has also been found on cacao (*Theobroma cacao* and *T. leiocarpa*), but it is not certain whether the leaves were eaten or not. Many woods of cultivation and wild grasses are also among the food-plants, but none of these has been identified with certainty.

It is only rarely that *S. flavofasciata* is an economic pest, but the nymphs have been known to be present in sufficient numbers to destroy completely several acres of sugar cane owing to some set of factors favouring the insect (Ulrich, 1915 a, p. 160, and Anonymous, 1915).

Nymphs have much the same feeding habits as the adults, although, of course, they cannot reach the leaves of trees. The first, second, and sometimes the third, instars differ from the adults in their method of feeding, in that they do not bite pieces from the edge of the leaf, but chew small holes in the lamina, unless the tissues are old.

Although feeding is general, however, there seems to be a fairly marked preference for various plants. In captivity, maize seems to be preferred above all else, being eaten even when completely dried up; the leaves of banana and *Canavalia* are eaten more readily than those of savannah grass or *Hibiscus*, while the insects seem to be reluctant to eat Guatemala grass, or Bahama grass (*Capriola (Cynodon) dactylon*).

In captivity, the insects were fed almost exclusively on *Canavalia* (Leguminosae) as it was readily accepted, and there was a ready source of supply. Maize and banana leaves—particularly the former—were also taken readily, but they tended to dry out and wilt more rapidly than *Canavalia*. It is of interest to note that Köhler (1936,

p. 83) states that *S. paranensis* has a marked preference for Leguminosae, which he suggests may be of some importance in the process of sexual maturation.

In captivity, under crowded conditions, with too little or undesirable food, or food which is *too dry*, there is a distinct tendency towards cannibalism. The insects chew each others wings and tegmina, and bite holes in the integument of the abdomen of other individuals, weakening the victims so that they become moribund, their bodies thereafter being eaten by the healthy insects. Insects which become sick for other reasons are also devoured, but only when the natural food supply is inadequate or unsuitable.

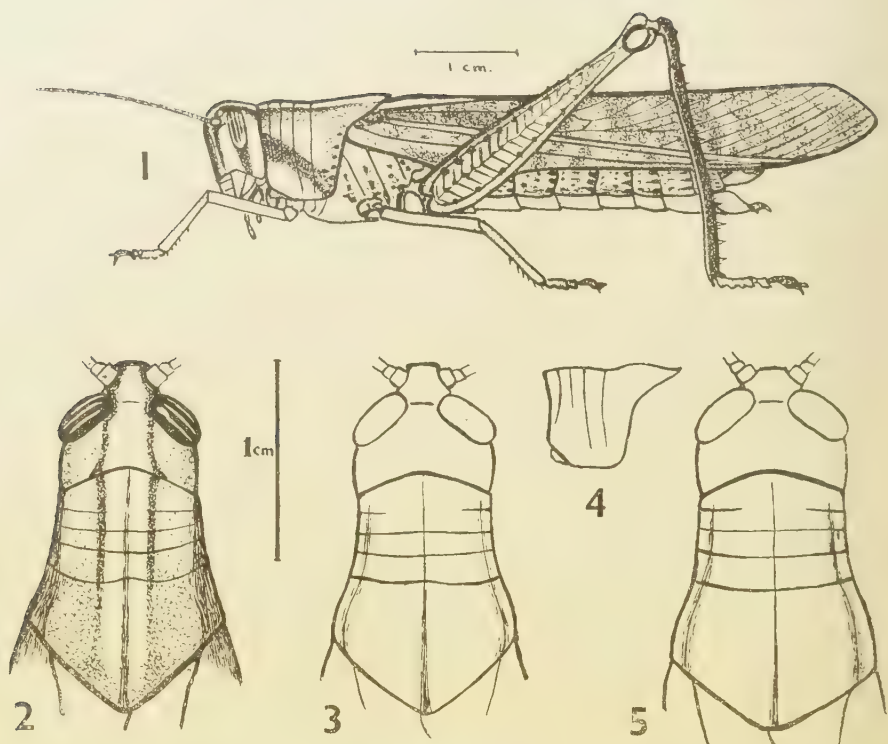
With regard to the time (after emergence from the egg) at which the young nymph begins to feed, first-instar nymphs only seldom feed on the day of emergence. Nymphs about to moult are relatively inactive, not taking in food for at least twenty-four hours before moulting, the older nymphs fasting for as much as three days or more, though about sixty hours would appear to be more usual in last-instar nymphs. This first permits the alimentary canal to empty in preparation for the sloughing off of the wall of the fore and hind guts. The insects immediately after moulting also fast for some time, the duration of which was not observed.

The Adult (figs. 1-2).

Colouration.

The general ground colour of the head, thorax and abdomen is a rather dull biscuit colour or buff, which is paler ventrally. Figs. 1 and 2 show the type of marking found in less heavily pigmented forms. The posterior margin of the pronotum and pleurae and the abdominal terga are maculated with black to a greater or lesser degree as shown; the vertex of the head and the dorsocentral region of the pronotum bear a stripe of yellow which varies from pale greyish yellow in some forms to reddish yellow in others, and extends from the fastigium to the posterior margin of the pronotum—occasionally observed at its extremities—the margins of this stripe being black, which becomes more suffused laterally. The face below the eye bears a cuneiform black mark, and the facial region just anterior to this is yellow, varying to pale grey-buff or whitish. The pronotum bears laterally a black crescentic mark as shown in fig. 1 and the region below this is of the same colour as the face in front of the cuneiform mark. The eye is yellowish, barred with four dark brown stripes, giving the whole a blackish brown appearance. The antennae are pink to red, usually paler ventrally grading to buff. In specimens of the more heavily pigmented form which usually has the head and pronotal markings pale greyish buff, the antennae are often entirely buff, scarcely tinged with pink even dorsally. The tegmina are brown to grey-brown with a rather obscure sepia brown pattern which is more clearly defined in the darker forms. The costal area is paler, and the anal region without any pattern is particularly noticeable when the insect is at rest. The hind wings are pale lemon-yellow basally, gradually becoming sepia-brown (veins) or infuscated (membrane) towards the apical and basal margins. The first and second pairs of legs are of the usual buff ground colour, sometimes with dark maculations on the femora in the more heavily pigmented forms, and their tarsi are darker apically. The hind femur is biscuit coloured or buff with the knee, and often the lower part of the herringbone pattern, very much paler, though not white as in some species. Black maculations occur as illustrated. The knee is sometimes pinkish on its lower half.

The hind tibia is dark green above, sometimes with pink underlying it (especially in older specimens), and buff, pinkish buff or greenish below. The tibia bears dorsally a series of eleven inner, and ten outer, bright yellow, black tipped spines. The tarsus of the hind leg is buff or pink, becoming darker apically, and the claws and arolia of all the feet are buff with black apices.



Figs. 1-5: Fig. 1. *Schistocerca flavofasciata*, ♀. Fig. 2. Ditto, head and pronotum of normal female. Fig. 3. Ditto, head and pronotum of abnormal female. Fig. 4. Ditto, pronotum of abnormal female, lateral view. Fig. 5. *S. pallens*, head and pronotum of female.

On ageing and becoming senescent, the whole colouration deepens and becomes dull, and a slight almost imperceptible purplish tinge undertones the basic colouration. The hind tibiae usually becomes deep purple, mottled with, and more or less obscured, by fairly large patches of very dark green above.

S. flavofasciata is a polychromatic species, and numerous references have been made above to "more heavily pigmented forms."

In the field, the insects can be more or less readily divided into two categories. These are (a) the paler type with fewer and smaller maculations on the pronotum, pleurae, abdomen and femora, having a more obscure tegmen pattern and with brighter and more yellow pale areas on the face and sides of the pronotum, and (b) those with more and heavier maculations on the pronotum, pleurae, abdomen and femora, having a more distinct tegmen pattern and duller and more greyish white pale areas on the face and sides of the pronotum. This varying degree of maculation of the thorax, abdomen, etc., has probably added considerably to the confusion in taxonomy of this species (and the genus *Schistocerca* as a whole), as seems to have been the case with the allied East Asiatic genus *Palanga* (Rehn & Rehn, 1940, p. 260).

Type (a), which is by far the commoner form in the field, appears at rest to be more of a yellow-brown colour, in contrast to type (b), which has a more grey-brown appearance. Many intermediate forms exist, and the two categories are by no means rigid,

varying considerably among themselves in the intensity of pigmentation. Exceptionally pale forms of type (a) are more frequent than very dull forms of type (b).

It has been suggested by Rehn & Rehn (1940, p. 259) that the occurrence of dichromatism in *Schistocerca* and *Valanga* is probably more dependent on genetic than on physiological factors, and with the idea of discovering if there were actually any genetic relationship between the colour forms of *S. flavofasciata*, a small experiment was carried out.

A fairly average male and a rather dark female of type (a) from the field had been isolated in a cage, and the female had already laid eggs before the experiment was devised, but, when the nymphs emerged, 16 of them were isolated in separate cages

TABLE I.

Biometry of Adult Schistocerca flavofasciata.

No. examined	Sex	Source of Material	Total length in mm.			Tegmen length in mm.			Femur length in mm.			E/F Ratio		
			Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
33	♂	Field	69.5	63.0	66.0	56.5	51.0	53.5	31.0	28.0	29.5	1.86	1.74	1.81
27	♀	Laboratory (Crowded)	63.5	58.0	61.0	51.0	46.0	49.0	30.0	26.0	28.0	1.83	1.67	1.75
14		Laboratory (Solitary)	62.0	56.5	60.0	49.0	46.0	47.5	28.0	26.5	27.0	1.83	1.70	1.75
40	;	Field	47.5	44.0	46.0	38.5	35.0	37.0	21.0	19.5	20.5	1.87	1.71	1.81
32	;	Laboratory (Crowded)	52.5	45.0	47.0	43.0	35.0	37.5	23.0	19.0	21.0	1.88	1.73	1.79
8	;	Laboratory (Solitary)	47.5	43.5	45.0	38.0	35.0	36.0	21.0	19.0	20.0	1.84	1.70	1.80

TABLE II.

Biometry of Adult Schistocerca pallens.

No. examined	Sex	Source of Material	Total length in mm.			Tegmen length in mm.			Femur length in mm.			E/F Ratio		
			Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
9	♂	Field	71.0	66.0	69.0	58.0	53.0	55.5	32.5	29.5	31.0	1.84	1.70	1.80
6	;	Field	54.0	52.0	52.5	44.0	42.0	42.5	24.5	22.9	23.0	1.91	1.80	1.85

and kept under exactly similar conditions. Of the 16 nymphs only 12 reached maturity, but of these 12 adults (of which seven were females and five males), five females and three males were of type (a)—one female being very pale—and two females and two males of type (b), though one female of each type and two males of type (a) were borderline cases (*vide* Table VI).

This small experiment, though by no means conclusive, tends to show that environmental factors do not influence the intensity of pigmentation, or at least are not the primary cause of any difference.

A pair of dark and a pair of pale examples of the F1 were then isolated in separate cages, but the pale pair unfortunately produced no F2 offspring.

Fifteen of the F2, from the dark pair, crowded in a single cage, survived to the adult stage, though only two of these were females, and all but five of them were type (b)—one female and four males, three of the latter were borderline cases. This evidence would seem fairly conclusive as to the genetic character of the pigmentation factor, since all the examples were reared under the same conditions. However, the crowded conditions of the F2 may have had some influence on the production of the dark forms, as the majority of nymphs reared in captivity under crowded conditions, but whose pedigree was unknown, produced dark adults.

Dimensions.

The adult males and females of *S. flavofasciata* differ very conspicuously in size, the average total length of material taken from the field being 46 mm. in the male and 66 mm. in the female (Table I).

Abnormalities.

Under experimental conditions of crowding, it was noticed that occasionally an adult appears with an abnormal pronotum.

A hump occurs on the metazona, which in some cases is very marked (fig. 4). The small keel of the pronotum becomes slightly more emphasised, and there is a distinct, though slight, pronotal constriction (fig. 3). All gradations down to the normal condition have been observed, and it was thought at first that the crowded conditions may have been the cause of the abnormality—perhaps the first signs of phase transformation—but a specimen showing a fairly conspicuous pronotal hump was found in nature. All specimens showing this phenomenon were of type (b) colouration, though this may be purely coincidental.

Comparison with S. pallens.

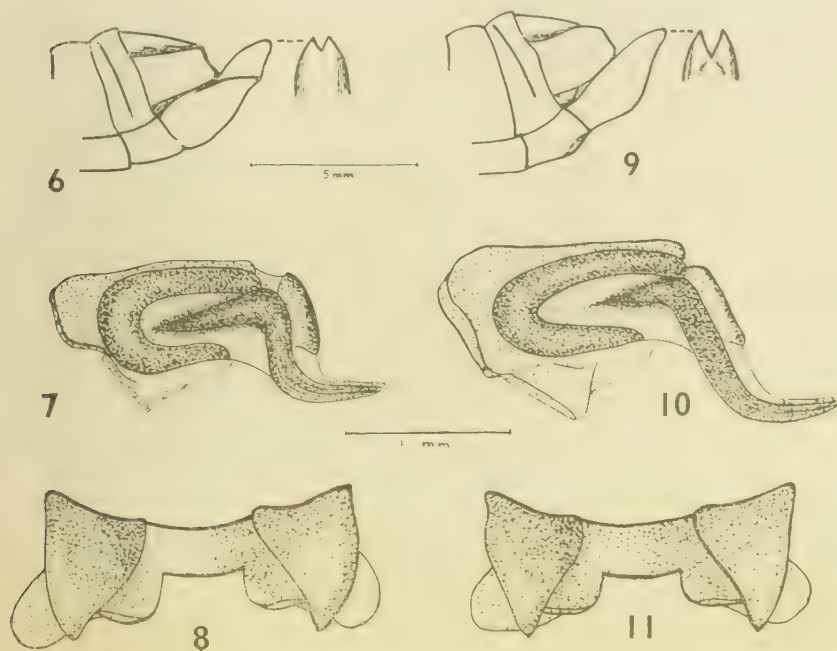
It may be useful to compare the present species with *S. pallens*, the other solitary species of the genus in Trinidad.

In general appearance *S. pallens* is rather more slender and a little larger, having a slightly more marked pronotal constriction, comparable with that of abnormal *S. flavofasciata* mentioned above. The astigium is somewhat broader and less prominent (fig. 5).

The colouration is the most outstanding feature of difference, that of *S. pallens* being much brighter. The two black dorso-central stripes on the pronotum are much wider (2.2–5 mm.), the costa of the tegmen is very conspicuously pale yellowish, and the lower part of the "herringbone" pattern of the hind femur is white, sometimes bordered above by a narrow dark brown line. Dried specimens of *S. flavofasciata*, however, may tend to simulate this last character. The hind tibiae and tarsi of *S. pallens* are bright pink or red, and not green as in *S. flavofasciata*.

The males and females of *S. pallens* also differ markedly in size, the average overall length of the female being 69 mm., and of the male, 52.5 mm. (Table II).

The males can also be distinguished by the external genitalia as shown in figs. 6 and 9. The cerci and the subgenital plate seem subject to slight variation in both species, but the cleft in the apex of the latter would appear always to be wider in *S. pallens*. No difference was observed in the epiphallus (figs. 8 and 11), but the aedeagus differed appreciably, as may be seen from figs. 7 and 10.



Figs. 6-11. Fig. 6. *Schistocerca flavofasciata*, ♂, end of abdomen and subgenital plate viewed from below. Fig. 7. Ditto, aedeagus. Fig. 8. Ditto, epiphallus. Figs. 9, 10, 11, *S. pallens*, ♂, corresponding structures.

Life History.

Maturation.

It has recently been shown by Bruch (1939, p. 163) that the imaginal diapause in *S. cancellata* (Serv.) in the Argentine, is of very short duration, being scarcely 40-50 days in all, and Lieberman (1939, p. 198) states that there is evidence that *S. paranensis* does not have a true imaginal diapause but a simple suspension of development dependent entirely on external factors.

Humidity plays an important part in the sexual maturation (Hamilton, 1936), and since Trinidad has a high and fairly even temperature (29° C.) and a high humidity, it is not surprising to find that *S. flavofasciata* shows only a very short maturation period.

The time required by the female between the attainment of the adult form and the laying of fertile eggs varies between 31 and 47 days, averaging 41 days, which means that sexual maturity is reached a day or so earlier. Copulation of males and females was not taken as an indication of maturity, since very frequently the two inse-

no relation to one another (Uvarov, 1928, p. 55). The males, which complete their development in a shorter time than the females, would appear to have a slightly longer maturation period, for while the first attempt to mate with virgin females of the same brood often resulted in the production of fertile eggs, they were not observed to copulate with older females till about five weeks after the last ecdysis.

The following are observations on the maturation of the female :—

Adult state attained	5.ii.42, fertile eggs laid	23.iii.42 after 47 days.
" " "	28.ii.42, " " "	30.iii.42 after 31 days.
" " "	21.v.42, " " "	2.vii.42 after 43 days.
" " "	21.v.42, " " "	1.vii.42 after 42 days.
" " "	21.v.42, " " "	3.vii.42 after 44 days.

Other observations were made during both wet and dry seasons which corroborate these results, but the exact date of oviposition was not noticed. In addition, loose batches of infertile eggs (discussed later) were laid as follows :—

Adult state attained	5.ii.42, infertile eggs laid	19.iii.42 after 43 days.
" " "	21.v.42, " " "	22.vi.42 after 32 days.
" " "	23.v.42, " " "	24.vi.42 after 32 days.

These infertile eggs were all laid without copulation having been observed.

Number of Generations per Year.

In Trinidad, *S. flavofasciata* may be found in all stages at all times of the year, and as the whole life cycle from egg to egg may not exceed four months (in captivity at least), there is room for three generations annually. This has been achieved in the laboratory, but it is doubtful if more than two and a half generations are gone through in a year in nature.

The length of life of the adult is short, not exceeding four months in captivity, about three months being usual, while some individuals lived only ten weeks after their final moult, up to which time they seemed perfectly healthy.

Mating.

The proportion of males to females, calculated from Trinidad material from all sources, is males, 53.75 ; females, 46.25.

Immediately before copulation, the male usually flutters and rustles the wings excitedly. He then leaps on to the back of the female, and clasps her with the two anterior pairs of legs, the claws of the fore tarsi being hooked under the lower margins of the pronotum of the female, and those of the middle tarsi round the bases of the costae of the tegmina. The hind legs play no part in copulation—they do not even need to be present—and are kept in an elevated position during the process. At intervals throughout the operation, the male flutters his wings, and the hind legs may even be agitated up and down slowly—a process perhaps akin to the type of stridulation so characteristic of the ACRIDIDAE. The mating process does not normally occupy more than about half an hour, and may be even less, but not infrequently it lasts from two to four hours or more. Both males and females pair repeatedly with no apparent regard to the stage of development of the eggs within the ovary of the female (*cf.* Uvarov, 1928, p. 55).

Oviposition.

Oviposition follows mating after a fairly short interval—usually on the following day, sometimes within less than 24 hours, but periods of as much as two days and more have been noted.

The number of matings required to produce fertile eggs for the first time was not studied, but on at least one occasion oviposition after a single pairing has been observed.

Fertilisation, however, is not necessary for the production of eggs by the female, but in such cases they are deposited in irregular masses, bound loosely together and laid on the surface of the soil (or even adhering to plants, etc.) together with large quantities of froth.

Unfertilised eggs are usually sterile, though a few parthenogenetic nymphs were obtained by burying the egg-masses in soil. These nymphs did not survive.

The female is unaccompanied by the male during the oviposition—contrary to what is usual in *S. paranensis* (Bruch, 1936, p. 194). She wanders slowly over the ground, the ovipositor often making digging motions in the air, and then, without probing the soil to determine its suitability, digs a hole between four and six centimetres deep, inclined backwards at an angle of about fifteen degrees from the vertical. In fairly loose soil, this takes from one to one and a half minutes, but longer when more resistance is encountered. Firm, slightly damp soil seems to be preferred, but does not appear to be important. After the hole has been dug, the insect may or may not oviposit. If it does not, it wanders slowly off and repeats the whole process, and this may be done as many as five times before a suitable piece of soil is found.

Oviposition is preceded by a slight contraction of the abdomen and the closing of the valves of the ovipositor, followed by the extrusion of a frothy secretion from the accessory glands. When all the eggs have been laid, large quantities of froth continue to be secreted so that the burrow is filled up to within about half a centimetre of the surface of the soil. Oviposition is then complete, and the female wanders off. The hole is not filled in, but particles of soil soon fall into the cavity and the site of the egg-pod becomes completely obscured. The whole process of oviposition takes about one hour.

The Egg-Pod and the Egg.

The number of egg-pods laid by a single female was found to be one, seldom two.

The normal egg-pod of *S. flavofasciata* is fairly similar to that of *S. paranensis* (Bruch, 1936, pl. XXX) or of *S. gregaria* (Uvarov, 1928, fig. 42), but it is a little smaller, and the eggs are not quite so loosely held together. Eggs are only found in the lower half of the pod and are irregularly arranged. In the region containing the eggs, the pod is covered with adhering particles of soil, small rootlets, etc.

In size the pods measure from $3\frac{1}{2}$ to $5\frac{1}{2}$ cm. long by about 1 to $1\frac{1}{2}$ cm. at their widest point. They contain from 48 to 82 eggs, averaging about 64 in each.

The eggs themselves are, when laid, approximately 7 mm. long by about 1.5 mm. broad and covered with hexagonal reticulations.

There is a slight increase in size as development proceeds, with the result that the egg-pod becomes fragile and difficult to handle without disintegrating as hatching time approaches. The colour of the egg is bright orange when laid and changes little until nearly ready to hatch, when it becomes greyish brown.

There is no embryonic diapause in *S. flavofasciata*. Under normal conditions the incubation period averages 36 days (nine observations), and varies between 32 and 39 days. One batch, however, which was transferred from its original position to dry sand remained 47 days before emergence took place.

Husain and Ahmad (1936, pp. 206–229) show that the incubation period in *S. gregaria* is 18 to 21 days at 28.8°C ., this being considerably less than for *S. flavofasciata* in Trinidad with a similar mean daily temperature.

The embryo within the egg develops a green colouration shortly before hatching.

Hatching occurs only by day and has been observed between the hours of 7 a.m. and 4.30 p.m. All the eggs hatch on the same day and usually all at one time, though in one case a period of about one and a half hours elapsed between the emergence of the first and second halves of the same brood.

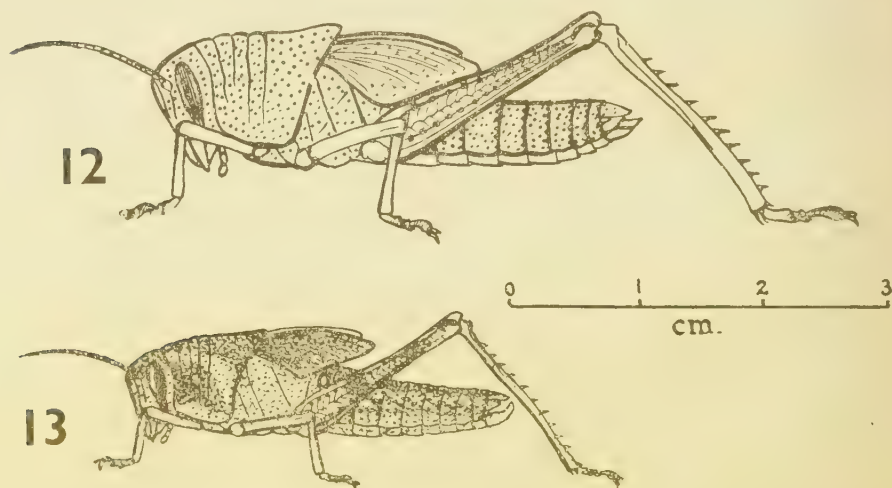
The vermiform larva is green, due to the green colour of the first-instar nymph showing through the colourless enveloping membrane, and it wriggles through the soil—or rather through the passage provided by the froth of the egg-pod—and reaches the surface, where it immediately goes through the “intermediate moult”, a process taking only one or two minutes.

Occasionally, if the soil is loose, the intermediate moult takes place below the surface of the soil (Uvarov, 1928, p. 43), and it is the first-instar nymph which emerges. Uvarov says that such nymphs are *not* able to reach the surface. This is not so in *S. flavofasciata*, though the occurrence has only been observed by the writer on two occasions; these two nymphs emerged through sand.

In eggs hatching on the surface of the soil, it was observed that the vermiform larva did not always completely free itself from the egg before the intermediate moult took place, but remained partially enclosed while this occurred. Only one nymph emerging thus was able to free itself completely from the larval exuvia, and it died soon afterwards.

The Nymph (figs. 12, 13).

In the field, all the nymphs observed (with one exception) were grass-green in colour, with minute blackish or dark blue-green maculations distributed over the body, and yellow fleckings on the posterior margins of the abdominal segments (fig. 12). The cuneiform mark below the eye varies somewhat in intensity. The earlier stages are a rather darker shade of green, with the yellow fleckings more pronounced and not confined to the hind margins of the abdominal terga, but generally distributed all over the body. The tibial spines in all stages are bright yellow, with black tips.



Figs. 12-13. Fig. 12. *Schistocerca flavofasciata*, female hopper of 6th instar, usual colouration. Fig. 13. Ditto, male hopper of 5th instar, colouration frequent in captivity.

The colouration of the nymphs in captivity—observations upon which will be made later in this paper—seldom conforms with that found in the field, except in the first instar. The commonest colouration by far (after the first instar which is always green) is black and greyish white, as shown in fig. 13. When the black markings are less intense, the nymphs appear grey—sometimes almost homogeneous pale greyish when the pattern is faint. Very frequently the mottling was blackish on pale buff,

giving a brownish tinge to the insect, and indeed a certain amount of sepia-brown pigment is laid down in the integument of both this and the preceding colour forms. This pigment is found in the areas of denser colouration and is distinct from the black maculations which show up as small points in the exuviae of all colour forms to a greater or less degree, including green specimens from the field.

Green was not uncommonly developed in captivity, but it was only rarely that a true grass-green was obtained, the colour being usually grey-green or dull olive-green, somewhat obscured by black pigment spots. Green forms such as these were obtained from any of the previous colour types on moulting, and sometimes reverted to the latter at the next ecdysis, though retaining a faint greenish tinge. Grass-green individuals, however, remained the same throughout all instars in the few cases observed, except for the last, when a dull green colour mottled with black was assumed—in one case very heavily pigmented, resulting in a very striking insect.

Unicolourous blue-green specimens were not obtained, but a single example of a bright orange colouration was obtained. This colour was maintained through several instars, but became duller after the fifth moult. Only once has a specimen been taken, or even seen in the field, of other than grass-green colour. The example was a fifth-instar male of the black and buff type, taken in a forest clearing with green specimens, at Cumaca, 10.viii.42.

The number of nymphal instars in the female is six, and in the male, five. No exceptions to this have been observed. The additional instar in the female is accounted for by its much larger size. In the development of the male, the fourth instar is, in effect, omitted, since it is at this stage that the males can be distinguished from the females. The fourth-instar female has small rounded wing-buds in a lateral position similar to the three previous instars, but in the male, the fourth-instar nymphs have the wing-buds much more prominent, further developed, triangular, and dorsal in position, corresponding with the fifth instar in the female, from which it can be readily told apart by its smaller size. The fifth (and last) nymphal instar of the male resembles the sixth of the female (figs. 12 and 13) and has the wing-buds fully developed, but it corresponds with the fifth-instar female in size.

From a study of the literature, it would appear that in *Schistocerca paranensis* the normal number of nymphal instars is five in each sex, but Bodkin and Cleare (1919, pp. 350-353) mention six occurring in the British Guiana locust, presumably *S. paranensis*. They do not, however, separate the sexes, or mention any sexual dimorphism, but it is not unreasonable to suppose that in this case a state of affairs corresponding with that found in Trinidad exists. The writer would suggest that a difference in the number of nymphal instars is general in New World species of the genus, such as *S. pallens*, where the two sexes differ conspicuously in size.

An account of the measurements of each instar and the duration of each stadium is given below in tabular form (Tables III, IV).

Table V gives the increase in size with each ecdysis based on 14 specimens (13 of which reached the adult stage), reared singly in cages.

TABLE III.
Duration of the Stadia in Days.

Stadium	1st	2nd	3rd	4th	5th	6th (♀)
Maximum duration	13	13	13	14	20	17
Minimum duration	8	4	7	7	6	13
Mean duration... ..	9.85	7.38	8.22	9.28	11.21	15.20
Number examined	31	31	28	28	28	15

TABLE IV.

Dimensions of Nymphs in mm.

Instar	1st	2nd	3rd	4th	5th	6th (♀)
Approximate overall length ...	7.5	9.0	13.0	18.0	28.0	38.0
Maximum femur length ...	4.8	6.6	9.0	12.6	17.0	22.5
Minimum femur length ...	4.8	6.2	8.0	10.0	13.0	18.0
Mean femur length ...	4.8	6.3	8.4	11.2	15.0	20.6
Number examined ...	66	62	55	56	63	35

TABLE V.

Increases in Length of Femur at each Ecdysis.

Instar to which nymph moulted ...	2nd	3rd	4th	5th	Female 6th	Male Imago	Female Imago
Maximum increase (in mm.)	1.8	2.7	3.6	4.5	6.8	6.0	7.0
Minimum increase (in mm.)	1.4	1.6	2.6	3.0	5.5	5.0	6.5
Mean increase (in mm.) ...	1.5	2.2	2.7	3.0	6.4	5.5	6.8
Number examined ...	14	14	13	13	7	6	7

The number of antennal joints in the various instars (excluding the base) is: I, 13-14; II, 16-17; III, 18-20; IV, 21-23; V, 24-25; VI (females), 26; adult males, 26; adult females, 27.

Moulting.

Ecdysis occurs only by day, and for a considerable period before moulting the nymph takes no food. The alimentary tract is thus cleared, and for some time before the moult the adult colouration can be vaguely distinguished below the nymphal integument.

The whole process of moulting takes almost exactly one hour. The actual time taken for the wings to harden and become ready for flight depends largely on the humidity at the time of moulting.

The moulting process of nymphs is exactly similar except for the absence of wings, which considerably shortens the time taken to complete the moult. About a quarter of an hour is all that is required by such nymphs—slightly less in the youngest stages.

Natural Enemies, Parasites, etc.

Birds, Insects, Mites and Parasitic Worms.

Urieh (1915a, p. 160) has noted that "*Schistocerca praesignata*" (*S. flavofasciata*) in Trinidad is eaten in considerable numbers by the tick-bird, *Crotophaga ani*.

No insect predators or parasites of any stage of *S. flavofasciata* have been recorded from Trinidad. The same is true for parasitic worms.

The larvae of unidentifiable Trombidiid mites are occasionally found on *S. flavofasciata*, but they do not seem to be common.

Fungi.

There is an anonymous reference (1915) which quotes Urich as saying that the solitary *Schistocerca* in Trinidad is affected by a green muscardine fungus. The writer has never observed this, but it is presumably *Sporotrichum* sp., the "hongo verde" of South American authors.

Marchionatto (1933) records the genus *Aspergillus* as attacking the egg-pods of *Schistocerca* in the Argentine, but in rearing *S. flavofasciata* in Trinidad, it was the nymphs that were attacked by one or more species of this fungus, which proved very troublesome in the breeding cages.

Nymphs are attacked under humid conditions approaching saturation, and the first instar (which is delicate and does not tolerate handling) is the most susceptible to the disease, but the second and even the third instars are also heavily attacked. The disease, however, has not so far been observed in the field.

Under very moist conditions, all instars up to the fifth are attacked, and it is improbable that the sixth-instar females are immune, though it would appear, from specimens confined with infected nymphs, that adults are so.

In the first instar, the first sign of attack is an emaciated appearance with a dulling of the green colour. The antennae then droop characteristically from about the middle, and coordination of movement and the ability to leap are lost, movement itself being slowed down. Meanwhile, white hyphae and conidiophores push out between the segments of the abdomen, and occasionally at other intersegmental membranes, such as at the bases of the antennae or the hind legs. The insect is usually killed in a day or two. The fungal hyphae never become very obvious.

In the second and later instars, the antennae do not droop, and the fungus may take several days to more than a week to kill its host, or the insect may even survive—though it becomes malformed in the region of attack, and is sluggish in its movements. Moulting is frequently inhibited by the presence of the fungus, and the nymph may outlive its normal span by several weeks, after which it dies. Infected nymphs have never been known to reach the adult state.

The fact that the fungus does not necessarily kill its host within a short period is unusual. Older nymphs are more likely to survive than young ones.

The fungus seems to be chiefly a wound parasite in the older instars, but the thin integument of young nymphs of the first and second instars seems to allow direct penetration by a germinating spore.

The fungus seems to require fairly special conditions to cause a serious epidemic, for in two similar cages in close proximity to one another, and each containing about sixty young nymphs, a very considerable difference in the intensity of the attack was noticed (early June 1942). In one cage, mostly first instars, all but three were killed, while in the other only about a dozen died from the disease, which spread from the first cage. The only difference in the two cages was that the nymphs in the latter had emerged straight into their cage without being handled, while those in the former had been transferred from one cage to another by means of a suction tube, and since newly emerged nymphs are delicate, they were perhaps weakened. Both the batches of nymphs emerged on the same day, but the infection of those in the first cage occurred some days before it spread to the second, by which time conditions (though still very humid) may have changed sufficiently to be unsuited to the continuance of the fungus on an epidemic scale.

Nymphs kept in glass cylinders with glass covers became extremely readily infected, even in dry weather, owing to the high humidity in the cylinders.

In dry weather, even in the open type of cage, the fungus is not entirely absent, and is always likely to appear, but only in isolated cases. Once the nymphs have been reared past the second instar, the disease is easily controlled by keeping the insects in well-aired cages. Supplying wilted food, instead of fresh, also helps.

Bacteria (Coccobacillus acridiorum d'Herelle).

A disease attacking the adults caused many deaths, both of males and females, during the rainy weather of early January, late July and early August, 1942. The symptoms of the disease bore a close resemblance to those described by d'Herelle and caused by *Coccobacillus* (Uvarov, 1928, p. 191), but the bacterium itself was not isolated. The insects were healthy one day and dead or dying the next, the faeces were moist blackish green, adhering to plants, and the integument became dark. Large numbers of minute coccoid bodies (presumably the pathogen) were found in the intestine.

Males seemed more susceptible to attack, but it is doubtful if this was actually the case. Nymphs in contact with diseased material were in no case observed to succumb.

Insects were quarantined before introducing them to the breeding cages in order to avoid epidemics.

The Colouration of Nymphs and Adults.

In captivity, the majority of adult specimens reared were of type (*b*) colouration, but whether this was due to the crowded conditions under which most of them were kept, or to the accidental formation of a dark strain, is not certain, since the evidence so far obtained is inconclusive.

Certainly there seems to be a tendency for dark nymphs to produce dark adults (see Table VI), but although under crowded conditions most of the nymphs were found to be dark, this was not an absolute rule, and nymphs reared under solitary conditions may produce dark examples of the extreme type (Table VI).

From evidence given previously (p. 297), heredity would be a factor of some importance in influencing adult colouration, but its effect may be intensified by environmental conditions such as crowding—or whatever other factor it is that influences the pigmentation of the nymph—since Table VI suggests strongly that dark-coloured nymphs usually produce type (*b*) adults, and light-coloured nymphs, type (*a*).

It is very important to notice that, in the field, type (*a*) adults of *S. flavofasciata* predominate, while, with but a single exception, all nymphs occurring naturally were found to be grass-green in colour. Type (*b*) adults, however, are not nearly so rare in the field as mottled nymphs. Unlike *Osmilia flavolineata* (De Geer) or *Orphulella punctata* (De Geer)—two abundant species of Trinidad Acridids—there is a uniformity in the nymphal colouration of *Schistocerca flavofasciata* found in the field, which is almost absolute, even the shade of green varying but little—so different from what is found in captivity.

In a few small experiments, in which painted floors to the cages, and cages with coloured cellophane jackets (and white floors, reflecting the colour of the cellophane) were used, the insects—with one exception, probably coincidental—gave absolutely no response either to background or to direct light. The colours used for the experiments were red, blue, green, yellow and white.

In the single example of a positive result, a first-instar nymph was put in a cage with a green cellophane jacket, and it remained green, though not pure green, throughout its whole life. Other nymphs treated in a similar manner gave negative results, which is not surprising in the light of Faure's work (1932, pp. 331-333, 356-362), who found that green colour in the nymphs of *Locustana* and *Locusta* was produced

TABLE VI.
Nymphal Colour Changes.

Cage No.	Instar						
	First	Second	Third	Fourth	Fifth	Sixth (Female)	Adult
1	Green	Dark Green	Greenish-Grey	Grey-Brown	Grey	Grey (more pattern)	Type (a) (Border-line)
2	Green	Dark Green	Grey-Green	Brown	Brown	—	Type (a) (Border-line)
3	Green	Green	Dark Green	Black and Whitish	Black and Whitish	—	Type (b)
4	Green	Dark Green	Dark Green	Grey-Brown	Blackish Buff	—	Type (a) (Border-line)
5	Green	Dark Green	Grey and White	Black and Pinkish-White	Black and Whitish	—	Type (b)
6	Green	Yellow-Green	Yellow	Yellow-ochre	Orange-Yellow	Orange	Type (a) (Very pale)
7	Green	Green	Grey	Greenish-Grey	Dull Green	Pale Greyish-Green	Type (a)
8	Green	Green	Green	Grass-Green	Olive-Green and Grey	—	Type (a)
9	Green	Dark Green	Pale Grey-Brown	(Died)	—	—	—
10	Green	Green	Green	Brownish-Green	Grey-Brown and Buff	Brown and Buff	Type (a)
11	Green	Green	Yellow-Green	Grass-Green	Green	Pinkish Brown	Type (a)
12	Green	Green	Green	Green	Grass-green	(DIED)	—
13	Green	Green	Grey and Buff	Yellow-Brown	Grey-Green	Black and Whitish	Type (b) (Border-line)
14	Green	Grass-Green	(Died)	—	—	—	—
15	Green	Green	Grass-Green	Grass-Green	Green	Intense Black and Whitish	Type (b)
16	Green	Green	Grey-Green	Grey	Grey	—	(Died)

only under humid conditions with abundant green food, and Key (1936, pp. 82-83) confirms this in the latter species.

Several attempts were made by the writer to rear nymphs of *S. flavofasciata* under exceptionally humid conditions by keeping them in glass cylinders with glass tops, to see if green forms could be produced in captivity, but epidemics of *Aspergillus* broke out in every case and destroyed all the nymphs.

The Effect of Crowding.

Owing to the considerable confusion which still exists with regard to the identity of swarming locusts in South America, it was decided, early in the investigation on *S. flavofasciata*, to see whether this species, under conditions of crowding, would produce a swarming phase.

It was, however, borne in mind that Rubtsov (1935) has shown the existence of distinct phases in certain Siberian non-migratory grasshoppers, so that a positive result in the case of *S. flavofasciata* would do no more than act as an indication that this species could possibly produce a swarming form.

The experiment consisted of crowding numbers of first-instar nymphs in the hemispherical meat-cover type of cage, and noting the effect of this treatment on the activity of the nymphs and on their colouration, compared with those reared solitarily under the same conditions. The colouration of the adults resulting from these nymphs was also observed and their biometry studied.

The cages were approximately 13 cm. in diameter, so that the floor area was almost 180 sq. cm., the area of the gauze 530 sq. cm., and the volume 880 cub. cm.

Concentrations of up to 60 nymphs were used, equivalent to one nymph for every 3 sq. cm. floor space, or for every 12 sq. cm. surface area, each nymph having a space of $14\frac{2}{3}$ cub. cm. in which to move.

By the time that the final instar was reached, a survival rate of as much as 25 per cent. was unusual. The results of the experiments would all appear to be negative. Nymphs under crowded conditions showed no increase in activity when left undisturbed, though agitation of the cage stimulated them into activity for a minute or so, one nymph influencing another to jump. The effect, however, soon wore off.

Neither nymphs nor adults reared under crowded conditions showed any difference from isolated specimens, though on the whole they were of darker appearance, but this may have been due to the accidental occurrence of a dark strain, as suggested previously (pp. 297, 306). Similar dark forms of nymphs and adults have been obtained in isolation and from the field. 68 per cent. of the adults reared under crowded conditions were of type (b) as against only 12.5 per cent. when isolated.

Table I (p. 297) gives an account of the tegmen and femur lengths and the E/F ratios of solitary and crowded individuals, and it is quite obvious that there is no attempt at the formation of a morphologically distinct type simulating a gregarious phase.

It is interesting to note that, under laboratory conditions, both solitary and crowded, the females were smaller than those obtained in the field, though this was not the case with the males, which, when crowded, give figures larger than those from field specimens. It is also interesting to find that both males and females reared under crowded conditions seem to be slightly larger on the whole than those reared in isolation. This is contrary to the state of affairs usually found in gregarious species, where the solitary phase is the larger.

While discussing biometry, the reader is again referred to the occurrence of the abnormal pronotum found in certain individuals mentioned on p. 298. Rehn *et al.* (1942) considers this abnormality to be merely teratological, though he has not

examined the specimens. This may be the case, or it may possibly be of genetic origin, owing to the frequency of its occurrence in a single batch of adults, where all gradations were found, and also to its occurrence in nature—a single example. Certainly it cannot be regarded as physiological.

From the above evidence it would appear that *S. flavofasciata* is unable to form a gregarious phase, and is therefore not likely to become an agricultural pest of major importance, though occasionally becoming troublesome locally (Ulrich, 1915 a, and Anonymous, 1915).

References.

- ANONYMOUS. (1915). Locusts.—Bull. Dep. Agric. Trin. Tob., **14**, p. 64.
- BODKIN, G. E. & CLIFARE, jr., L. D. (1919). An invasion of British Guiana by locusts in 1917, with a complete illustrated account of the life history of the species.—Bull. ent. Res., **9**, pp. 341–357.
- BRUCH, C. (1936). Investigaciones sobre la langosta en la region serrana de Alta Gracia (Provincia de Cordoba).—Mem. Com. cent. Invest. Langosta, 1934, pp. 173–202.
- . (1939). Investigaciones sobre la langosta experimentos en cautividad (verano 1935–36 y parte de 1937).—*Ibid.*, 1936, pp. 143–170.
- BRUNER, L. (1906). Report on the Orthoptera of Trinidad, West Indies.—J. N. Y. ent. Soc., **14**, pp. 135–165.
- DAGUERRE, J. B. (1939). Informe de la comision investigadora del Este.—Mem. Com. cent. Invest. Langosta, 1936, pp. 107–141.
- DE GEER, C. (1773). Mémoires pour servir à l'histoire des insectes, **3** (4), p. 489, pl. 40, fig. 8. (Not seen.)
- FAURE, J. (1932). The phases of locusts in South Africa.—Bull. ent. Res., **23**, pp. 295–424.
- FREEMAN, W. G. (1915). Report on locusts in Venezuela.—Bull. Dep. Agric. Trin. Tob., **14**, pp. 191–194.
- HAMILTON, A. G. (1936). The relation of humidity and temperature to the development of three species of African locusts—*Locusta migratoria migratorioides* (R. & F.), *Schistocerca gregaria* (Forsk.) and *Nomadaeris septemfasciata* (Serv.).—Trans. R. ent. Soc. Lond., **85**, pp. 1–60.
- HEBARD, M. (1923). Studies in the Dermaptera and Orthoptera of Colombia, third paper, Orthopterous family Acrididae.—Trans. Amer. ent. Soc., **51**, pp. 285–287.
- HUSAIN, M. A. & AHMAD, T. (1936). Studies in *Schistocerca gregaria* Forsk. II. The biology of the desert locust with special relation to temperature.—Indian J. agric. Sci., **6**, pp. 188–262.
- KEY, K. H. L. (1936). Observations on the rate of growth, colouration, and the abnormal six-instar life-cycle in *Locusta migratoria migratorioides* R. & F.—Bull. ent. Res., **27**, pp. 77–85.
- KIRBY, W. F. (1910). Synonymic Catalogue of Orthoptera, **3**, pp. i–x, 1–674. British Museum (Natural History).
- KÖHLER, P. (1936). Informe de la segunda comision exploradora.—Mem. Com. cent. Invest. Langosta, 1934, pp. 71–95.
- . (1937). Informe de la comision investigadora del Oeste.—*Ibid.*, 1935, pp. 11–69.

- LIEBERMANN, J. (1939). Informe acerca de los trabajos realizados en el insectario de José C. Paz en 1936.—*Ibid.*, 1936, pp. 191-231.
- . (1939a). Catalogo sistematico y biogeografico de acridoideos argentinos.—*Rev. Soc. ent. Argent.*, **10**, pp. 125-230.
- LYNCH ARRIBALZAGA, E. (1918). La langosta voladora de Colombia y Venezuela.—*Physis*, **4**, pp. 49-79.
- MARCHIONATTO, J. B. (1933). Parásitos vegetales de la langosta. (*In*) Parásitos mas importantes de la langosta (*Schistocerca paranensis* Burm.) en la República Argentina.—*Bol. Minist. Agric. Argent.*, **34**, pp. 227-245.
- . (1934). Los hongos parásitos de la langosta en la República Argentina. (*In*) Comisión nacional de defensa contra la langosta. Lucha nacional contra la langosta. Contribución científica de la Sociedad Entomológica Argentina, pp. 43-53. Buenos Aires, Minist. Agric. Argent.
- REHN, J. A. G. (1916). The Stanford expedition to Brazil, 1911, J. C. Branner, director. Dermaptera and Orthoptera I.—*Trans. Amer. ent. Soc.*, **42**, pp. 215-308.
- & REHN, J. W. H. (1940). The Orthoptera of the Philippine Islands, part II—Acrididae; Cyrtacanthacridinae; group Cyrtacanthacrides.—*Proc. Acad. nat. Sci. Philad.*, **92**, pp. 245-287.
- RUBTZOV, I. A. (1935). Phase variation in non-swarming grasshoppers.—*Bull. ent. Res.*, **26**, pp. 499-520.
- SCUDDER, S. H. (1899). The Orthopteran genus *Schistocerca*.—*Proc. Amer. Acad. Arts Sci.*, **34**, pp. 441-476. (Not seen.)
- SERRE, P. (1916). L'Ile de Trinité menacée d'une invasion de sauterelles.—*Bull. Mus. Hist. nat., Paris*, **2**, pp. 101-104 [*R.A.E. (A)* **5**, p. 192].
- URICH, F. W. (1915). Locusts or grasshoppers.—*Bull. Dep. Agric. Trin. Tob.*, **14**, pp. 120-128.
- . (1915a). Insects affecting the sugar cane in Trinidad.—*Ibid.*, **14**, pp. 156-161.
- . (1916). Notes on the South American locust, *Schistocerca paranensis* Burm.—*Ibid.*, **15**, pp. 15-16.
- . (1916a). Notes on the South American migratory locust (*Schistocerca paranensis*).—*Ibid.*, **15**, pp. 172-173.
- UVAROV, B. P. (1928). Locusts and grasshoppers, a handbook for their study and control, pp. xiv+352 pp. London, Imp. Bur. Ent.

A NEW SPECIES OF *FINLAYA*, THEO. (DIPTERA, CULICIDAE) FROM USSURI LAND.

By A. A. STACKELBERG.

Zoological Institute, Academy of Sciences, Stalinabad, Tadzhikistan, U.S.S.R.

***Aedes* (Finlaya) alektorovi, sp. n.**

A dark species of medium size: praescutum with a large quadratic spot covered with golden-yellow scales. Abdominal segments with small white-scaled lateral spots. Hind tarsi with apical and basal bands on joints 1-3.

♂. *Head* dark, covered with pale yellowish erect scales; eye-margins with many long black bristly hairs (ocular chaete). Proboscis black and black-scaled. Palpi a little shorter than proboscis, black, covered with black scales, in apical part a little clubbed; apical and preapical joint of palpi with some long dark hairs. *Antennae* dark brown, with pale bands and a tuft of long blackish hairs. *Mesonotum* black, covered with numerous golden-yellow scales; lateral area of praescutum with a small spot of blackish-brown scales; lateral area of scutum with a similar spot. Scutum between the dorsocentral bristles covered with blackish-brown scales. Mesonotal bristles golden-yellow. Scutellum covered with pale yellow scales, with three groups golden-yellow bristles. *Pleurae* brown. Dorsal margin of proepimera covered with yellowish sickle-shaped scales; caudal margin of proepimera with a small spot of broad silvery-white scales. Dorsal part of sternopleura with a large spot of broad silvery-white scales, in the middle of caudal margin a similar but much smaller spot. Dorsal part of mesepisterna with a distinct spot of broad silvery-white scales. *Abdomen* black, with dorsum of all segments densely covered with black scales with steel-blue reflexions; bases of tergites with triangular lateral spots of broad silvery-white scales. *Hypopygium*: coxite cylindrical, four times as long as broad at base; basal part of coxite with a small lobe-like prominence, armed with seven long and stout bristles. Style long lancet-like, slightly broadened before the middle, at the apex with a long cylindrical appendage. Harpago with long right stem and long, in basal part cylindrical, in apical part flattened blade. Lobes of 9th tergite very distinct, triangular, with rounded apices, at apex with seven short and stout bristles. Legs dark, covered with black scales with steel-blue reflexions. Basal part of femora posteriorly white scaled. Femora narrowly pale at apices. Base of the first tarsal joint on middle legs, bases and apices of first, second and third joints on hind legs silvery-white banded. Ungues on front and middle tarsi long and thin, with a long tooth-like process at base; unguis on hind tarsi short, without process. Wings dark brown scaled. Wing about 3.5 mm.

Distribution: Many males were taken by Prof. Dr. A. S. Montshadsky near Kamenushka, district Shkotovo, Ussuri Land, S.E. Siberia, in August 1937.

Type in the collection of the Zoological Institute, Academy of Sciences, Leningrad.

NATURAL ENEMIES OF THE CACAO THRIPS.

By E. McC. CALLAN, B.Sc., A.R.C.S., D.I.C., Ph.D.

Imperial College of Tropical Agriculture, Trinidad.

Introduction.

Thrips as a group have remarkably few effective natural enemies. Their parasites comprise Hymenoptera, Nematodes and entomogenous fungi. The Hymenopterous parasites have been reviewed by Sakimura (1937) and include among others, *Dasyseipus parvipennis*, Gahan, and some ten species of the genus *Thripoctenus*, of which *T. russelli*, Crwf., and *T. brui*, Vuillet, are the best known. Predators comprise, in addition to other species of thrips, Anthocorids, Capsids, Lygaeids, Reduviids, Chrysopids, Coccinellids, Cecidomyiids, Syrphids, ants, mites and spiders.

The cacao thrips, *Selenothrips rubrocinctus*, Giard, a native of tropical America, is now widely distributed and is an important pest of cacao in the West Indies, West Africa and Brazil; it also attacks mango, cashew, avocado, guava and many other plants. Its natural enemies include at least one Hymenopterous parasite, one or more species of entomogenous fungi and numerous predators.

Previous Records.

The well known entomogenous fungus, *Beauveria globulifera* (Speg.), attacks the cacao thrips. Nowell (1916, 1917) records it in Grenada and St. Vincent, B.W.I. and reports that unsuccessful attempts have been made to utilise it artificially. Russo (1936) records it attacking the cacao thrips in Santo Domingo. Myers (1931) notes that a similar fungus occurs in Trinidad. Williams (1918) found in Panama a similar fungus destroying both larvae and adults. Reyne (1921) records in Surinam a species of *Cephalosporium* on a living cacao thrips larva. Ulrich (1928) reports in San Thomé an entomogenous fungus destroying all stages.

In Trinidad, Ulrich (1911) states that the cacao thrips has no natural enemies of any importance, but later (1918) observes that in Grenada a Chrysopid and in Trinidad several Reduviids exercise some measure of control.

Williams (1918) makes the observation that in Trinidad no efficient natural enemies are known. He notes that in Guadeloupe an ant, *Wasmannia auropunctata*, Roger, was seen carrying off young cacao thrips, and that in Trinidad the larvae are also destroyed by the predacious thrips, *Frankliniethrips vespiformis*, Crwf., and *F. tenuicornis*, Hood, and by small Reduviids.

Reyne (1921) records in Surinam the following species of Chrysopids, the larvae of which are predacious on the cacao thrips: *Leucochrysa marquezii*, Nav., *L. submacula*, Bks., *Chrysopa montana*, ? Nav., and *C. claveri*, Nav. These are rare predators and occur only in the proportion of about one per thousand thrips. Reyne also records *Frankliniethrips tenuicornis* and *F. vespiformis* as predators, but only in about the same proportion. Reyne also mentions as additional predators an Anthocorid, *Triphleps* sp., and several Reduviids in Trinidad and a Capsid, *Paracarnus* sp., in Grenada and St. Lucia, B.W.I.

Ulrich (1928) states that in San Thomé larvae of *Chrysopa* sp. and a species of *Triphleps* were found preying on all stages.

Cotterell (1927, 1928) states that natural enemies of the cacao thrips in the Gold Coast comprise an undetermined predacious thrips, small spiders and the internal

Eulophid parasite, *Dasyscapus parvipennis*, Gahan, parasitism by which may reach as high as 80 per cent. following periods of heavy infestation.

Myers (1931, 1935 a) reviews the literature on natural enemies of the cacao thrips, recommending the introduction of *D. parvipennis*, into the West Indies from the Gold Coast. He also erroneously recorded *Baryconus* sp. as an egg parasite of the thrips from Bahia, Brazil. I am indebted to Senhor Pedrito Silva for pointing out this error. Myers (1935 b) records the Capsid, *Termtaphylidea pilosa*, Reut. & Popp., as a predator in Jamaica.

Kaden (1934) reports an undetermined Hymenopterous parasite of the cacao thrips in Costa Rica.

Bondar (1939) states that in Bahia, Brazil, the cacao thrips is attacked by various predators such as Coccinellids, Chrysopids and *Frankliniothrips vespiformis*.

Natural Enemies in Trinidad.

In Trinidad the natural enemies of the cacao thrips comprise the Eulophid parasite, *Dasyscapus parvipennis*, Gahan, introduced in 1935 from the Gold Coast, an entomogenous fungus, probably *Beauveria globulifera* (Speg.) and numerous predators. The predators include the predacious thrips, *Frankliniothrips tenuicornis*, Hood, and *F. vespiformis*, Crwf., the Chrysopids, *Leucochrysa varia*, Schn., *Chrysopa claveri*, Nav., *C. alobana*, Bks., *C. iona*, Bks., and *C. arioles*, Bks., various Reduviids, the Capsid, *Termtaphylidea maculosa*, Usinger, the Lygaeid, *Ninyas torvus*, Distant, the ant, *Wasmannia auropunctata*, Roger, and various small spiders.

Dasyscapus parvipennis, Gahan.

This species was described in 1928 from specimens reared from the onion thrips in Java. It was first recorded as a parasite of the cacao thrips in the Gold Coast by Cotterell (1927, 1928). Adamson (1936) gives an account of its introduction into Trinidad and of its life history and describes the technique of breeding it in the laboratory and liberation in the field.

Between 1936 and 1942, *D. parvipennis* has been sent from Trinidad to the United States, Canada, Hawaii, Puerto Rico, Jamaica, Bermuda and Grenada for the control of various species of thrips. It has been successfully established in Trinidad, Puerto Rico and Jamaica. In the latter island this fact has not hitherto been reported. It was introduced there in 1937, and recoveries were not made until 1942, when, in company with Mr. W. H. Edwards, I found it at two localities at Hope on the Liguanea Plain parasitising the cacao thrips on mango.

Professor A. M. Adamson has kindly provided me *in litt.* with the following information on *D. parvipennis* in Trinidad. Extensive liberations were made from 1935 through 1936 in many parts of the Island in order to provide every possible chance of establishment, and they proved successful. From 1935 to 1940 search for parasites yielded negative results in most places; such recoveries as were made comprised only small numbers indicating a parasitism of considerably less than 0.1 per cent. From 1941 to 1943 recoveries suggested an increase in the numbers of parasites.

In 1942 to 1943 recoveries were made in many places widely scattered over the island on cashew and in a few cases on cacao, notably at Diego Martin, Maracas, Gran Couva and San Rafael. Counts in very restricted areas comprising only a single or at most a few cacao trees gave a parasitism of at least 20 per cent. and in some cases of over 30 per cent. On cacao plants in a semi-open greenhouse at St. Augustine the parasitism rose to nearly 100 per cent. late in 1942, and from then until April 1943 the cacao thrips was apparently controlled in this greenhouse by the parasite. Recoveries on hosts other than the cacao thrips have been made on *Heliothrips*

haemorrhoidalis, Beh., and *Hercothrips insularis*, Hood, and hosts parasitised in the laboratory have included *Thrips tabaci*, Lind., and *Dinurothrips hookeri*, Hood.

Though *D. parvipennis* is undoubtedly established in Trinidad, no indication of any economic control of the cacao thrips has so far been observed, and indeed is scarcely now to be expected. The parasite, however, was found in larger numbers in 1942 than in 1939, for example, and there is a remote possibility that it may be increasing sufficiently to justify some slight hope of eventual control by this means.

Franklinothrips tenuicornis, Hood.

Williams (1918) records this species as predacious on the cacao thrips in Trinidad. He states that it has been found on cacao, *Inga*, *Hibiscus* and *Ipomoea*, and that it is known from Trinidad and Panama. Reyne (1920, 1921) records it as a common predator of the cacao thrips in Surinam, and gives a good account of its peculiar habit of cocoon-spinning. Moulton (1932) records it from Panama, Venezuela and Brazil, and suggests that *F. petulans*, Bagnall, described on cacao leaves from Trinidad, is probably a synonym.

* The adult is black and ant-like, and very similar in general appearance to *F. vespiformis*. The larva is yellowish with a very conspicuous broad bright red band on the first six abdominal segments and a narrow red band at the end of the ninth segment. Both larva and adult are very active and are predacious, sucking the juices of other small insects, including other species of thrips.

The fully fed larva spins a cocoon, which is attached to a cacao leaf, usually in the angle formed by the midrib and a lateral vein. Within this cocoon the larva pupates. According to Reyne (1920), there appears to be no prepupal stage. Reyne concludes that the spun threads forming the cocoon are probably produced from the mouth, although Bailey (1940) found that in other cocoon-spinning thrips they were produced from the anus. Reyne also suggests that the peculiar hook-like appendage found on the fore legs of the adult may be used in breaking open the cocoon on emergence.

In Trinidad I have found this species on cacao as a common predator of the cacao thrips and the greenhouse thrips, *Heliothrips haemorrhoidalis*, Bouché. It is certainly much the commoner of the two species of *Franklinothrips* found on cacao. I have not found it, however, on plants other than cacao.

Franklinothrips vespiformis, Crawford.

Williams (1918) records this species as predacious on the cacao thrips in Trinidad. He states that it has been found on cacao, guava, sweet potato, bamboo, *Lantana* and on grass and various low shrubs, and that it is common throughout the West Indies and Central America. Reyne (1920, 1921) records it as a predator of the cacao thrips in Surinam, but notes that it is much rarer than *F. tenuicornis*. Moulton (1932) records it as predacious on mites, leafhoppers and whiteflies on citrus and avocado in Florida and Texas, U.S.A., Cuba, Nicaragua and Brazil. Russo (1936) records it attacking the cacao thrips on cacao and mango in Santo Domingo. Wolcott (1936) records it in Puerto Rico. Bondar (1939) records this species as a predator of the cacao thrips and greenhouse thrips in Bahia, Brazil.

The adult thrips is black with banded black and white wings and a white band at the base of the abdomen. It has long legs and antennae and is very ant-like in appearance. The larva is bright vermilion in colour with three narrow, pale yellowish bands near the end of the abdomen. Both larva and adult are very active and are predacious, sucking the juices of other small insects, including other species of thrips. My observations in Trinidad show that the fully fed larva spins a cocoon, within which it pupates, in a similar way to that described for *F. tenuicornis*.

In Trinidad I have found this species on cacao as a rare predator of the cacao thrips and greenhouse thrips. It is certainly very much rarer on cacao than *F. tenuicornis*. In Jamaica I have found it predacious on the cacao thrips on mango. In Trinidad I have also observed it on *Zinnia* and *Aster* as a predator of *Dinurothrips hookeri*, Hood; and on Sudan grass predacious on *Hercothrips insularis*, Hood.

Chrysopids.

The green lacewings known to be predacious on the cacao thrips in Trinidad comprise *Leucochrysa varia*, Schn., *Chrysopa claveri*, Nav., *C. alobana*, Bks., *C. iona*, Bks., and *C. aridula*, Bks. Mr. Nathan Banks kindly determined specimens for me. I am uncertain which of these species is the commonest and responsible for most control of the thrips. The life-histories of them all appear to be very similar. The eggs are attached by long delicate stalks usually to the underside of the cacao leaf, either singly or in batches of a dozen or more. On hatching, the larvae immediately begin to search for its prey, which comprises all stages of the cacao thrips and any other small soft-bodied insects. It possesses a pair of conspicuous sickle-like mandibles which are used to extract the body contents of the prey. The larvae have the characteristic habit of covering themselves with the remains of their victims, thereby concealing their bodies, a habit that probably confers on them a certain measure of protection. The fully fed larva spins a spherical silken cocoon on the leaf from which the adult emerges. In Trinidad the eggs of these Chrysopids are commonly attacked by the Encyrtid parasite, *Ooencyrtus chrysopae*, Crawford, and an Eulophid, a new species of *Horismenus*, has been reared from the cocoons. Specimens were kindly determined by Dr. A. B. Gahan.

Ninyas torvus, Distant.

This Lygaeid was originally described from Panama, and Professor C. J. Drake has kindly identified specimens for me. It is an interesting insect, which has not hitherto been recorded from the West Indies. The adult is 4.5 mm. in length, pale ochraceous in colour with the scutellum darker and the head and eyes bright coralline-red. The eyes are very large and prominent, being exserted and directed backwards. Adults were frequently observed feeding on cacao thrips larvae on cacao leaves at Brasso, Trinidad, but not elsewhere. Specimens were obtained in February, March and April 1940. The Lygaeids are normally regarded as plant-feeding insects. This species, therefore, differs from other members of the family in being predacious. The adults are very active, running on the surface of the leaves in search of prey. When disturbed, they show amazing agility and almost invariably take to flight. In feeding, the thrips larvae is transfixed by the proboscis and its juices sucked out, the larvae being often lifted from the leaf in the process.

Termtophylidea maculosa, Usinger.

This Capsid originally described from Central Mexico has not hitherto been recorded from the West Indies. It was determined for me by Professor C. J. Drake. The only other member of the genus, *T. pilosa*, Reut. & Popp., was described from Jamaica, where Myers (1935) records it on cacao as a predator of the cacao thrips. The adult is 3.8 to 4.0 mm. long, the females being slightly larger than the males. The antennae are quite different in the two sexes; in the male the second antennal segment is stout and cylindrical, in the female it is slender and very gradually thickened from base to apex. The general colour is fuscous. The surface is glabrous, covered with long fulvous to white hairs. The head is tinged with red, the eyes silvery, tinged with red, the antennae ochraceous, the first segment more or less red, and the legs testaceous. Both nymphs and adults were observed on cacao and cashew leaves feeding on cacao thrips larvae at St. Augustine, Trinidad. Specimens were obtained in November and December 1939 and again in January 1941. This species was also observed on Sudan grass feeding on the grass thrips, *Hercothrips insularis*, Hood, at St. Augustine.

in November 1940. Nymphs were successfully reared to adults in the laboratory when fed on cacao thrips larvae. Nymphs and adults are normally very active, but when engaged in sucking the juices from their prey are not readily disturbed.

This species has not been encountered feeding on the cacao thrips in Trinidad elsewhere than at St. Augustine.

Wasmannia auropunctata, Roger.

This ant is a widely distributed species and is commonly found on cacao. In Trinidad it occurs wherever cacao is grown, and it is usually associated with the citrus mealy-bug, *Pseudococcus citri*, Risso, and the black citrus aphid, *Toxoptera aurantii*, Boyer. It has been observed on a few occasions in Trinidad carrying cacao thrips larvae in its jaws.

Importance of Natural Enemies in Control.

Almost all previous workers have considered the natural enemies of the cacao thrips to be of little importance in its control, though, as already stated, Cotterell (1927, 1928) has recorded that in the Gold Coast parasitism by *Dacnusa parvipennis* may reach as high as 80 per cent. following periods of heavy infestation, but this parasite has so far given no indication of economic control in the West Indies. The entomogenous fungus, *Beauveria globulifera*, has possibly some slight beneficial effect during the rainy season. *Ninyas torvus*, *Termitophylidea maculipes* and *Wasmannia auropunctata* are all of negligible importance in control. /at

Franklinothrips tenuicornis and the less common *F. vespiformis* probably bring about some measure of control, but their importance is relatively small. In Trinidad I have found that they only occur in the proportion of 140 *Franklinothrips* larvae to 36,583 cacao thrips.

The Chrysopids are undoubtedly the most important predators of the cacao thrips, and probably exercise some measure of control wherever the pest occurs. Both these and the *Franklinothrips* appear to be more abundant in Trinidad than in Surinam, judging by the figures recorded by Reyne (1921).

Little is known of the bionomics of the predators of the cacao thrips. Adults of *Ninyas torvus* and both nymphs and adults of *Termitophylidea maculipes* destroyed several cacao thrips larvae per day in the laboratory. /at

In Trinidad I have found that the daily consumption of a single *Franklinothrips* larva is only one or two cacao thrips larvae, but that Chrysopid larvae destroy thrips larvae at the rate of about one or two per minute, though after a time they pause in their activities and may not resume feeding for some hours. In the laboratory a single Chrysopid larva consumed 20, 13, 11, 15 and 12 thrips larvae on five consecutive days.

If the feeding propensities of these predators in the laboratory are any indication of their activities in the field, they might be of somewhat greater importance, were they not such rare species.

In order to determine the importance of the natural enemies of the cacao thrips as control factors in Trinidad, a survey was carried out for a period of over two years, from November 1939 to December 1941, at Santa Severa estate in the Montserrat Hills of the Central Range. Population counts of the cacao thrips and Chrysopid and *Franklinothrips* larvae were made at fortnightly intervals on two experimental plots each comprising 20 cacao trees (see Table I).

In a previous paper (Callan, 1943), I have recorded that "thrips populations normally start to increase rapidly in Trinidad as the rainy season progresses, reaching a maximum in about November, when the main attack takes place, and then decreasing. A sudden increase in the population during the dry season from January to

TABLE I.

Population Counts of Cacao Thrips and its more important Predators in Trinidad.

Date	Cacao leaves examined	<i>Franklino- thrips</i> larvae	Chrysopid larvae	Cacao thrips larvae	Total cacao thrips
Nov. 1939 ...	952	2	31	832	1,792
Dec. 1939 ...	2,040	6	48	2,759	4,513
Jan. 1940 ...	631	4	13	618	1,122
Feb. 1940 ...	1,751	12	24	1,447	2,424
Mar. 1940 ...	1,578	3	21	1,033	2,042
Apr. 1940 ...	2,108	20	13	2,445	3,969
May 1940 ...	1,682	0	10	590	1,199
June 1940 ...	1,149	1	8	113	142
July 1940 ...	1,250	0	1	55	116
Aug. 1940 ...	2,626	15	14	462	801
Sept. 1940 ...	1,758	1	15	461	1,277
Oct. 1940 ...	2,851	2	24	1,539	2,965
Nov. 1940 ...	2,684	21	16	2,750	4,383
Dec. 1940 ...	1,782	15	28	1,036	1,920
Jan. 1941 ...	1,251	0	7	193	765
Feb. 1941 ...	1,900	13	11	612	1,041
Mar. 1941 ...	1,572	18	13	1,544	2,196
Apr. 1941 ...	825	0	0	155	305
May 1941 ...	1,600	2	3	28	64
June 1941 ...	800	0	0	35	58
July 1941 ...	1,625	0	1	39	109
Aug. 1941 ...	1,150	1	0	117	286
Sept. 1941 ...	1,625	2	8	439	1,125
Oct. 1941 ...	800	0	2	244	463
Nov. 1941 ...	850	2	2	412	799
Dec. 1941 ...	800	0	4	288	707
Total ...	39,640	140	317	20,246	36,583

April often occurs, and the population density may sometimes attain as high a level as that recorded in November".

The relative numbers of cacao thrips and Chrysopid and *Frankliniothrips* larvae from November 1939 to December 1941 are shown in fig. 1.

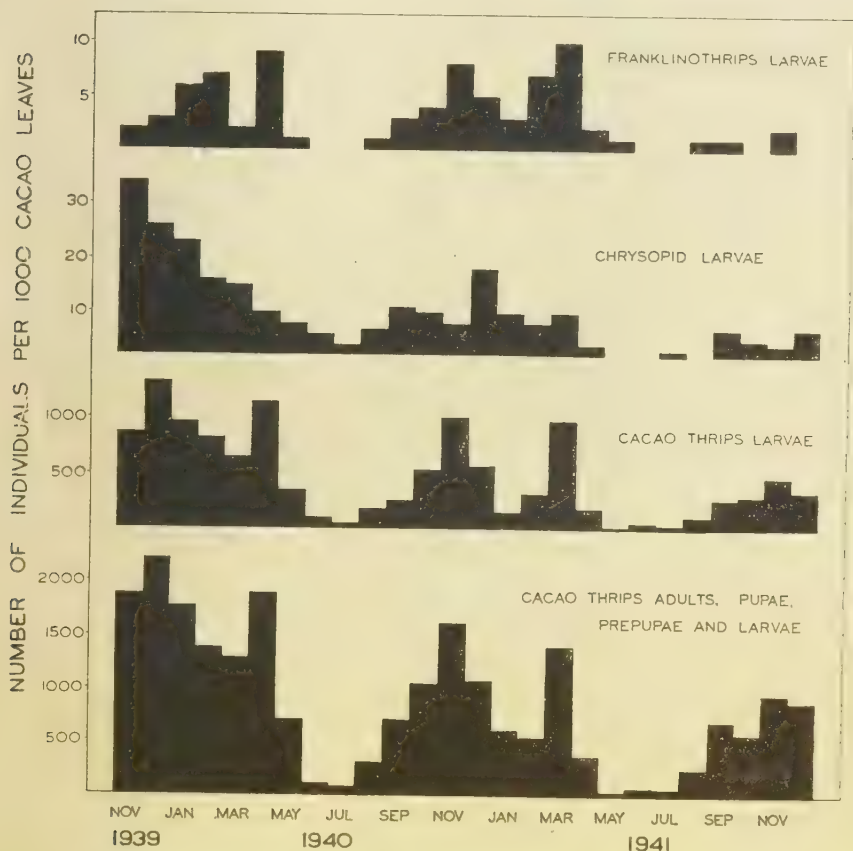


Fig. 1. Histograms of populations of the cacao thrips and its more important predators in Trinidad, B.W.I.

The histograms for the cacao thrips show that the maximum population occurs in November to December, with a secondary maximum in March to April, and that the population is at a minimum in May to July. The histograms for Chrysopid and *Frankliniothrips* larvae follow those for the cacao thrips very closely with maxima and minima at almost exactly the same times.

Summary.

(1) Previous records of natural enemies of the cacao thrips, *Selenothrips rubrocinctus*, Giard, are reviewed.

(2) An account is given of the following natural enemies in Trinidad, B.W.I.: *Dasyseipus parvipennis*, *Frankliniothrips tenuicornis*, *F. vespiiformis*, Chrysopids, *Ninyas torvus*, *Teratophylidea maculosa* and *Wasmannia auropunctata*.

105

(3) The Eulophid parasite, *Dasyscapus parvipennis*, was introduced into the West Indies from the Gold Coast in 1935. It is now successfully established in Trinidad, Puerto Rico and Jamaica, but has so far given no indication of economic control of the cacao thrips.

(4) The importance of natural enemies is discussed. Observations are made on the feeding propensities of some of the predators in the laboratory. Chrysopids are regarded as the most important predators and probably exercise some measure of control.

(5) Population counts of the cacao thrips and Chrysopid and *Franklinothrips* larvae are given.

Acknowledgments.

It is a pleasure to acknowledge my thanks to Professor C. J. Drake of Iowa State College, Mr. Nathan Banks of Harvard University, Dr. A. B. Gahan and Dr. J. C. Crawford, both of the U.S. Department of Agriculture, Washington, D.C., for the determination of the Heteroptera, Chrysopids, Chalcidoidea and Thysanoptera respectively. I am also indebted to Professor A. M. Adamson of the Imperial College of Tropical Agriculture for information on the status of *Dasyscapus parvipennis*, Gahan, in Trinidad, and to Miss P. C. Atteck for the drawing of Fig. 1.

References.

- ADAMSON, A. M. (1936). Progress report on the introduction of a parasite of the cacao thrips from the Gold Coast to Trinidad, B.W.I.—Trop. Agriculture, Trin., **13**, pp. 62–63.
- BAILEY, S. F. (1940). Cocoon-spinning Thysanoptera.—Pan-Pacif. Ent., **16**, pp. 77–79.
- BONDAR, G. (1939). Insetos daninhos e parasitas do cacau na Bahia.—Bol. tec. Inst. Cacau Bahia, no. 5, pp. 14–15.
- CALLAN, E. McC. (1943). Thrips resistance in cacao.—Trop. Agriculture, Trin., **20**, p. 134.
- COTTERELL, G. S. (1927). A new parasite of *Heliothrips rubrocineta*.—Bull. Dep. Agric. Gold Coast, no. 7, pp. 47–48.
- . (1928). The red banded cacao thrips, *Heliothrips rubrocinetus* Giard.—Bull. Dep. Agric. Gold Coast, no. 13, pp. 94–99.
- CRAWFORD, D. L. (1909). Some new Thysanoptera from Southern California.—Pomona Coll. Ent., **1**, pp. 109–110.
- DISTANT, W. L. (1880–93). Biologia Centrali-Americana. Insecta-Rhynchota, **1**, pp. 388–389.
- DOHANIAN, S. M. (1937). Life history of the thrips parasite *Dasyscapus parvipennis* Gahan and the technic for breeding it.—J. econ. Ent., **30**, pp. 78–80.
- GAHAN, A. B. (1928). Miscellaneous descriptions of new parasitic Hymenoptera with some synonymical notes.—Proc. U.S. nat. Mus., **71**, pp. 26–28.
- HOOD, J. D. (1915). On some American Aeolothripidae.—Ent. News, **26**, p. 164.
- KADEN, O. F. (1934). Die Bekämpfung des Kakaothripsen unter neuzeitlichen Gesichtspunkten mit Berücksichtigung der Verhältnisse in San Tomé, Golf von Guinea.—Tropenpflanzer, **37**, p. 148.
- MOULTON, D. (1932). The Thysanoptera of South America.—Rev. Ent., Rio de J., **2**, pp. 464–465.

- MYERS, J. G. (1931). Preliminary report on an investigation into the biological control of West Indian insect pests.—E.M.B. [Publ.], no. 42, pp. 120–122.
- . (1935 a). Second report on an investigation into the biological control of West Indian insect pests.—Bull. ent. Res., **26**, pp. 239–240.
- . (1935 b). Notes on cacao-beetle and cacao-thrips.—Trop. Agriculture, Trin., **12**, p. 22.
- NOWELL, W. (1916). The fungus on cacao thrips. Agric. News, Barbados, **15**, p. 430.
- . (1917). Preliminary trials with the cacao thrips fungus.—Agric. News, Barbados, **16**, p. 94.
- REYNE, A. (1920). A cocoonspinning thrips.—Tijdschr. Ent., **63**, pp. 40–45.
- . (1921). De Cacaothrips (*Heliothrips rubrocinctus* Giard). Bull. Dep. Landb. Suriname, no. 44, pp. 157–160.
- RUSO, G. (1936). Contributo alla conoscenza degli insetti della Repubblica Dominicana (Antille). Nota su alcuni Tisanotteri.—Mem. Soc. ent. ital., **15**, pp. 42–54.
- SAKIMURA, K. (1937). On the bionomics of *Thripoctenus brui* Vuillet, a parasite of *Thrips tabaci* Lind., in Japan.—Kontyû, **11**, pp. 371–374.
- URICH, F. W. (1911). The cacao thrips.—Circ. Bd Agric. Trinidad, p. 8.
- . (1918). Thrips, black ants and other insect pests of cacao in Grenada. Rep. to Govt. of Grenada, Trinidad, pp. 1–23.
- . (1928). San Thomé cacao industry.—Trop. Agriculture, Trin., **5**, p. 275.
- USINGER, R. L. (1935). A new *Termitophylidea* from Mexico (Hemiptera: Termitophylinae).—Ent. News, **46**, pp. 270–273.
- WILLIAMS, C. B. (1918). Notes on some Trinidad thrips of economic importance. — Bull. Dep. Agric. Trinidad, no. 17, pp. 143–146.
- WOLCOTT, G. N. (1936). Insectae Borinquensis. J. Agric. Univ. P. Rico, **20**, p. 64.

NOTES ON THE MOSQUITOS OF BRITISH SOMALILAND.

By G. R. CUNNINGHAM VAN SOMEREN.

In 1941 Edwards listed nine species from British Somaliland, comprising one Anopheline and eight Culicines. These were the specimens collected by R. E. Drake-Brockman in 1913 and by T. H. Twigg in 1930, but there appears to have been no detailed mosquito survey of the territory.

The present notes are based on a small collection made by the writer in January 1942, as a result of a brief survey in a limited area of the Protectorate, augmented by notes and material, mostly larvae, made by Dr. D. G. MacInnes from March to June 1942. Although only a few places were visited, the survey has added a further thirteen species to the list for the territory. Owing to circumstances, the restricted area investigated was confined to the region along the roads Boramo-Hargeisa to Berbera and Berbera to Burao, the altitude range being from sea-level to 5,000 feet.

Breeding Foci.

Along the coast some breeding places tended to be brackish, and one species of Anopheline and one Culicine were taken from almost pure sea water in a slit trench. The main breeding foci are the seepages in the "tugs," waterholes, wells, springs and rock pools. The mosquito population appears to be rather concentrated in the somewhat restricted breeding place with the result that several species were taken in large numbers at each dip.

It was noticeable that the water in most of the "tugs" smelt sulphurous and some of the abandoned deeper waterholes smelt strongly of sulphuretted hydrogen. In some "tugs" and springs there was a marked calcareous deposit on the stones, this was particularly noticeable at the Dubar Springs, the source of the water supply to Berbera. In one of the springs even the molluscs were coated with the deposit, giving them a pinkish or yellow appearance.

Some tree and rock-hole breeding undoubtedly occurs, but we visited the areas at the wrong time of the year to find larvae in these foci and as time was the determining factor, it was not possible to soak debris from the holes in order to obtain larvae.

The word "tug" is in general use in Somaliland to designate a water course or river bed. For their greater part the courses run through sandy areas. The actual river bed is excavated out to a more or less impervious strata but, as a result of silting up, the river has the appearance of a river of sand, thus for the greater part of the year there is little or no surface water, the water table being below the level of the sand. The water table varies according to the depth of the irregular impermeable strata and the extent to which silting has taken place. It often happens that where water is held up in a rock basin filled with sand, a seepage formation occurs over the lip of the lower barrier. The seepage may be connected with a more or less open sheet of water in a depression in the rock floor, and an example of this exists at Mandera, where water is held up by a wide rock barrier in which there is a large natural depression roughly 20 by 30 feet fed by seepage above. Below this barrier, water is obtained at a depth down to 30 feet in the sand bed.

There being little or no surface water, the Somalis excavate in the sandy river beds until the water level is reached; such excavations as already mentioned, form an important breeding focus for, as soon as the water begins to develop a growth of algae, such holes are abandoned and not filled in.

Dubar Springs.

These springs, 10° 21' N., 45° 03' E., altitude 656 ft., are seven miles inland from Berbera and consist of three sets of springs issuing from the Nahian Sandstone. They are led by drains to a central collecting filter point and then piped to Berbera, and they are remarkable in that, although all issuing within 200 yards, their temperatures are quite different, the central springs being hot with a temperature from 107°F. (41.7°C.) to 110°F. (43.4°C.) (Macfadyen, 1933), while that to the west is a warm spring and to the east cold.

A partial analysis of the (by Beeby Thompson, Macfadyen, 1933) water is as follows:—

Analysis—						Parts per 1,000,000.
Total soluble matter	...	...	...	...	...	2,240.0
Chlorine	...	...	...	...	...	580.0
Equivalent as NaCl	...	...	...	...	...	957.0
Sulphuric anhydride (SO ₃)	...	...	...	...	...	334.7
Lime (CaO)	...	...	...	...	...	176.0
Magnesia	...	...	...	...	...	110.7

Each spring contains different vegetation and fauna:—

The hot spring, no vegetation, but a "scum"-like brown and grey alga. No larvae, molluscs or insects.

The warm spring, *Spirogyra*, various grasses, an aquatic plant like *Vallisneria* or *Sagittaria* and another *Cabomba* or *Myriophyllum*. Molluscs (*Melanoides tuberculata*) are black with fine yellowish markings but in the spring were heavily coated with calcium sulphate. They were found literally in thousands. Numbers of aquatic insects were noted including nymphs of Odonata. The mosquito larvae found were *Anopheles turkhudi*, *A. d'thali*, *A. macmahoni*, *A. gambiac*, *Culex (Lutzia) tigripes*, *C. laticinctus*, *C. sinaiticus* and *C. ethiopicus*.

The cold spring contained little *Spirogyra*, no water plants and only grasses. The stones were not so heavily coated with deposits. No molluscs were found, and the mosquito larvae were *Anopheles turkhudi* and *A. d'thali*.

Rainfall.

Rainfall generally in the territory appears to be in the region of 2 inches per annum at the coast, and falls are recorded usually between November and April. In the highlands the average recorded is 21 inches falling between April and October, thus possibly giving rise to two distinct rainy seasons.

The incidence of mosquitoes could probably be correlated with rainfall with variation in the rise and fall of the flow of water in the tugs, there being a diminution during the period of floods. There would be, however, some compensatory breeding in the temporary pans and roadside excavations, but of short duration owing to rapid evaporation and soakage.

List of Species.

Identification of adults and larvae were carried out at the Medical Research Laboratory, Nairobi, by Mrs. E. C. C. van Someren and myself using the "Mosquitoes of the Ethiopian Region," Parts I, II and III, (Hopkins), (Evans) and (Edwards) for differential diagnosis.

Anopheles (Myzomyia) d'thali, Patton.

All the adult specimens agree well with the description given by Christophers (1933) and Evans (1938). Living and fresh specimens were noticeably greenish or yellowish and retained this colour for some days after pinning.

Larvae are typical, agreeing with the description given by Evans except in one feature, that of the tergal plates, which are more conspicuous and not so small as would appear to be the case in specimens from the Sudan as figured by Evans. The caudal bristles are extremely hooked. Larvae were found in many types of breeding places but seldom if ever where such breeding places contained algae (*Spirogyra*). The commonest foci were the seepages in the tugs, footprints, and shallow water holes dug in the sand by the Somalis, rockpools and brickpits. In Berbera larvae were taken in brackish water in the brickpits and in a slit trench on the foreshore in more or less pure sea water. On one occasion they were taken in a large open iron water conserving tank. At Dubar Springs in the "warm" and "cold" springs, larvae were numerous, some twenty to thirty being taken in a dip. They appeared to frequent the edges and were difficult to detect, their colour harmonising with the sand. This species was taken in company with *A. (M.) gambiae* in a few instances.

The adults were scarce, and very few were taken in adult catches; the tents did not appear to be an attractive harbourage as is recorded by Patton (1905) from Arabia (Evans 1938).

Localities: Berbera (sea level to 45 ft., Jan. '42); Dubar Springs (656 ft., Jan. '42); Mandera Camp (3,148 ft., Jan. '42); La Farug and nearby tugs (2,174 ft., Jan., Apr., May, '42); Manjessah (2,000 ft., Jan., Apr., '42); Lower Sheik, Middle Sheik, Upper Sheik (3,000 ft. 4,700 ft., Jan., Apr., '42); Boramo (5,000 ft., May, '42); Mile 58 Berbera-Hargeisa Road (3,400 ft., Mar., May, '42); Dubato (4,000 ft., Mar., May, '42); Tugs—Arjan and Gulel at Darbaruk (4,000 ft., May, '42).

Anopheles (Myzomyia) macmahoni, Evans.

Larvae apparently referable to this species were taken, but all attempts to breed out adults failed. Larvae appear typical but it is noticeable that all my specimens have only a single accessory tergal plate. They were not numerous, and some difficulty was experienced in finding them in a shaded grassy drain from the "warm" spring at Dubar.

The finding of this species extends its range from Isiolo, the type locality, and Archer's Post in the Northern Frontier Province of Kenya in a north westward direction. It is of interest to note that the breeding place at Archer's Post was a series of springs which were very alkaline and that the molluscs inhabiting the pools were of the same genus as those at Dubar (*Melanoides tuberculata*) and were coated with a whitish concretion.

The larvae are recorded from Manjessah (2,000 ft., April 1942) by MacInnes.

Anopheles (Myzomyia) gambiae, Giles.

The adults were typical in markings, but were generally paler when compared with East African material.

Larvae were pale coloured and not very numerous in January at any of the places visited. They were taken separately or together with *A. d'thali*. They were found in foci favoured by *A. d'thali* and were taken in the "warm" springs at Dubar. Adults were definitely not numerous.

This would appear to be the first record of this well-known malaria vector in Somaliland.

Localities: Berbera (0-45 ft., Jan. '42); Dubar (656 ft., Jan. '42); Mandera (3,148 ft., Jan. '42); Darbaruk, Tug Arjan (4,000 ft., May '42); Manjessah (2,000 ft., Apr. '42).

Anopheles (Myzomyia) turkhudi, Liston.

Adults are quite typical. In life they are decidedly green in colour, even more so than *A. d'thali*.

Larvae were tentatively identified as *A. (M.) cinereus*, and would have been reported as such at the time except for the chance hatching of an adult that had the tips of the palps black, which fortunately made me check all larvae again. The palmate hairs as suggested by Evans as being short and somewhat blunt appears to be a good character for the differentiation of the two species. Larvae were found to be very numerous indeed though hard to detect amongst the green algae, *Spirogyra*, for which they showed a partiality, their colour harmonising with the vegetation. The habit of the larvae, described by Patton (1905), of diving into the filaments of the algae and there remaining for long periods was amply demonstrated and extremely noticeable, so much so that I found it simpler to capture the larvae with a pipette, rather than with a ladle, which was apt to disturb all the larvae and send them hurrying to the bottom.

Breeding places were varied, but without exception contained algae whether in seepage in the tugs, shallow waterholes, rock pools or in springs ("cold" and "warm" at Dubar).

Only one adult was captured, and this was located in a crevice in rocks near pools that contained larvae and pupae. All the adults in my collection were bred.

Localities: Dubar (656 ft., Jan. '42); Mandera (3,184 ft., Jan. '42); Lafarug (Jan., Apr., May '42); Manjessah (2,000 ft., Jan. '42); Lower, Middle and Upper Sheik (3,000 ft., 4,700 ft., Jan., Apr., May '42); Tug at mile 58 Berbera-Hargeisa Road (4,000 ft., Mar., Apr. '42); Dubato (4,000 ft., Mar., Apr. '42).

Anopheles (Myzomyia) pretoriensis, Theo.

Adults were captured at Dubar and appear to be quite typical.

No larvae were found; it is possible that some of those thought to be *A. (M.) rhodesiensis*, Theo., in the field were of this species, but a re-examination of over 100 larvae collected at Dubar and Mandera show no *A. (M.) rhodesiensis* or *A. (M.) pretoriensis*.

Definite larvae are recorded by MacInnes from Dubato (4,000 ft., Mar. '42), Boramo (Damuk) (5,000 ft., May '42).

Anopheles (Myzomyia) rhodesiensis, Theo.

I recorded larvae from Dubar and Mandera in reports (January), but I am now somewhat doubtful of the identification as mentioned previously, as I could find no larvae of this species in the collection brought to Nairobi.

MacInnes records the species from Dubato (4,000 ft., Mar. '42).

Aedes (Stegomyia) aegypti, L., and var. *queenslandensis*, Theo.

Adults were numerous, and many colour variations were collected and bred. The colouration varied from the jet black to rich and pale brown forms to one specimen which was very pale brownish almost yellow. Sizes of individuals varied considerably, but the majority were found to be smaller than Kenya material and of the black form.

Larvae were quite typical and found very commonly in the small earthenware water storage pots so common in every Somali house or hut. Larvae were also located in the water tanks on the dhows, but never in the saline bilge water. Dhows which had just arrived in Berbera from Aden contained larvae in the fresh water tanks.

A larval index for Berbera township and camps in January was 7.7 per cent.

Localities: Berbera (0-45 ft., Jan. '42); Burao (3,424 ft., Apr. '42); Upper Sheik (4,700 ft., Apr. '42); Lafarug (2,174 ft., Apr.-May '42).

Aedes (Stegomyia) vittatus, Bigot.

Recorded by Twigg from Buran (Edwards, 1941). Larvae were collected from rockpools at Upper Sheik (4,700 ft.) and Gedeis, Apr. '42.

Aedes (Aedimorphus) hirsutus, Theo.

Larvae were collected at Upper Sheik (4,700 ft. Apr. '42).

Aedes (Aedimorphus) cummingsi, Theo.

Larvae were taken at Manjessah (Apr. '42-2,000 ft.).

Culex (Lutzia) tigripes, Theo.

Adults were collected and larvae found breeding in association with other Culicines.

Localities: Mandera (3,148 ft., Jan. '42); Dubar (656 ft., Jan. '42); Berbera (0-45 ft., Jan. '42).

At Berbera they were associated with *Culex simpsoni* in a deep pit in very saline water. At Dubar they were found in the "warm" spring.

Culex (Culex) ethiopicus, Edw.

A single adult was collected at Berbera Jan. '42.

Larvae of the "*bitaeniorhynchus*" group were recovered from the "warm" pool at Dubar and were probably of this species.

Culex (Culex) tritaeniorhynchus, Giles.

Larvae from El Qore. June '42.

Culex (Culex) sinaiticus, Kirk.

Recorded from British Somaliland by Edwards (1941). Breeding places are springs, wells, seepages in the tugs with and without waterweeds and algae. Adults and larvae numerous, Berbera (0-45 ft., Jan. '42), Gedeis, May '42, Upper Sheik, Apr. '42, Dubar, Jan. '42.

Culex (Culex) duttoni, Theo.

No adults were collected but larvae were found in a collection from Mandera (3,148 ft., Jan. '42).

Culex (Culex) univittatus, Theo.

Adults were bred from larvae collected at Mandera, Jan. '42, and larvae were found at Upper Sheik (4,700 ft., Apr. '42).

Culex (Culex) laticinctus, Edw.

Larvae of this species were found in the "warm" spring at Dubar (656 ft., Jan. '42), at Odweina in a 40 ft. well, together with *C. fatigans* (3,558 ft., Apr. '42), Gedeis (Apr. '42), Upper Sheik (4,700 ft., Apr. '42).

Culex (Culex) pipiens, Linnaeus.

A single specimen from Berbera, Jan. '42.

Culex (Culex) fatigans, Wied.

Adults were collected in huts and buildings at Hargesa (4,329 ft., Jan. '42), and larvae from a soakage pit in January, '42, also from Odweina (3,558 ft., Apr. '42), Burao (3,424 ft., Apr. '42).

Culex (Culex) sitiens, Wied.

Adults were extremely numerous and very common in houses in Berbera, and appeared almost to take the place of *C. fatigans* as a house-frequenting mosquito. Larvae were numerous, and a large series was collected. Breeding was in almost pure sea water in a slit trench on the foreshore at Berbera; in the brickpits it was in brackish water. Larvae were also collected at El Qore (Apr. '42).

Culex (Culex) decens, Theo.

A single male specimen was collected in Berbera. Larvae were found at Ainabo (2,338 ft., Apr. '42).

Theobaldia (Allotheobaldia) longiareolata, Macq.

From Burao (3,424 ft.), Drake-Brockman, (Edwards 1941).

References.

- CHRISTOPHERS, S. R. (1933). Fauna of British India, **4**, Anophelini.
DRAKE-BROCKMAN, R. E. (1913). Some notes on *Stegomyia fasciata* in the coast towns of British Somaliland.—J. Lond. Sch. trop. Med., **11**, pp. 166–169.
EDWARDS, F. W. (1941). Mosquitoes of the Ethiopian Region—Part III.—Culicine adults and pupae.
EVANS, A. M. (1938). Mosquitoes of the Ethiopian Region—Part II. Anophelini - Adults and early stages.
HOPKINS, G. H. E. (1936). Mosquitoes of the Ethiopian Region—Part I. Larval bionomics of mosquitoes and taxonomy of Culicine larvae.
PATTON, W. S. (1905). The Culicid Fauna of the Aden hinterland.—J. Bombay nat. Hist. Soc., **16**, p. 623.
-

GENERAL INDEX.

A.

- abyssinicus*, *Culex andersoni*.
Acanthomia brevirostris, Scelionid parasite of, in Sudan, 139.
Achaea, new Braconid parasite of, in Gold Coast, 59.
Achroia grisella, larval characters of, 167, 179.
aciculatus, *Eucorystes*.
Aclerda californica, 125.
Aclerda distorta, 125.
Aclerda sacchari, 125.
Aclerda thysanolaenae, sp. n., on *Thysanolaena agrostis* in Mauritius, 125.
Acrobasis caryae, larval characters of, 168.
Acrobasis juglandis, larval characters of, 168, 188.
Acrosternum pallidoconsersa, Scelionid parasite of, in Italian Somaliland, 141.
Acrosternum prunasis, new Scelionid parasite of, in Senegal, 142.
Aedes aegypti, breeding places of, in Syria, Eritrea and Br. Somaliland, 246, 280, 281, 326; control of, 285.
Aedes aegypti var. *queenslandensis*, breeding places of, in Eritrea and Br. Somaliland, 281, 326; a potential vector of yellow fever and dengue, 283.
Aedes alektorovi; sp. n., from Ussuri, 311.
Aedes caballus, in Eritrea, 280, 283.
Aedes cunminsi, in Br. Somaliland, 327.
Aedes detritus, 251.
Aedes echinus, 251.
Aedes eritreae, in Eritrea, 281, 283.
Aedes geniculatus, 251.
Aedes hirsutus, in Br. Somaliland, 327.
Aedes luteocephalus, in Eritrea, 281; a potential vector of yellow fever, 283.
Aedes mariae, in Syria, 246.
Aedes scatophagoides, in Eritrea, 280.
Aedes simpsoni var. *lilii*, in Eritrea, 281; a potential vector of yellow fever, 283.
Aedes vittatus, breeding places of, in Eritrea and Br. Somaliland, 281, 327.
Aedimorphus (see *Aedes*).
aegypti, *Aedes* (*Stegomyia*).
aegyptium, *Anacridium*.
Africa, *Microphanurus* spp. of, 135-144.
Africa, East, Hymenopterous parasites in, 57, 59, 60, 129, 131, 139, 141, 143.
Africa, South, Hymenopterous parasites in, 56-58, 60, 63, 140.
Africa, West, Hymenopterous parasites in, 59, 63, 266; new Mirid from, 287; *Sahlbergella* on cacao in, 159-162.
africanus, *Microphanurus*.
Aglossa caprealis, larval characters of, 170, 201.
Aglossa pinguinalis, larval characters of, 169, 200.
Agonoscelis versicolor, Scelionid parasites of, in Sudan and Uganda, 139, 143.
Alabonia bractella, 209.
alektorovi, *Aedes* (*Finlaya*).
Allotheobaldia (see *Theobaldia*).
alobana, *Chrysopa*.
aloytii-sabaudiae, *Microphanurus*.
americana, *Newsteadia*; *Schistocerca*.
ampullacea, *Lucilia*.
Anacridium aegyptium, breeding of, in captivity, 253.
Anacridium moestum, breeding of, in captivity, 253.
Anagyrus spp., morphology of, 129.
Anagyrus beneficans, sp. n., parasite of *Pseudococcus kenyae* in Uganda and Kenya, 129, 131.
Anagyrus fusciventris (*nigricornis*), synonymy of, 129 (note).
Anchonoma xeraula, larval characters of, 170, 206.
andersoni, *Culex*.
annulata, *Theobaldia*.
annulioris, *Culex*.
Anopheles cinereus, in Eritrea, 281, 282.
Anopheles claviger, in Syria, 247.
Anopheles coustani, effect of temperature and light on breeding of, 89.
Anopheles d'thali, breeding places of, in Eritrea and Br. Somaliland, 282, 325.
Anopheles funestus, effect of temperature and light on breeding of, 89-93.

Anopheles gambiae, breeding places of, in Br. Somaliland, 325; effect of temperature and light on breeding of, 89-93.
Anopheles macmahoni, breeding places of, in Br. Somaliland, 325.
Anopheles marteri, in Syria, 247.
Anopheles minimus, effect of temperature on breeding of, 89.
Anopheles pharoensis, effect of temperature and light on breeding of, 89.
Anopheles pretoriensis, in Br. Somaliland, 326.
Anopheles rhodesiensis, in Br. Somaliland, 326.
Anopheles sacharovi, in Syria, 247.
Anopheles superpictus, in Syria, 247.
Anopheles turkhudi, breeding places of, in Br. Somaliland, 326.
Antestia lineaticollis, Scelionid parasites of, in E. Africa, 142, 143.
Antestia variegata, Scelionid parasite of, in Africa, 143.
Apamea sordens, larval characters of, 166, 174.
Aphis cognatella, sp. n., on spindle tree in British Is., 213; bionomics and other food-plants of, 221-224.
Aphis euonymi, 213.
Aphis fabae, morphology and bionomics of, on spindle tree in British Is., 213-224.
Aphis rhamni, tests with plant insecticides against eggs of, 239-241.
Aphomia gularis, larval characters of, 167, 182.
Aphomia sociella, larval characters of, 167, 180.
Arctium lappa, new Aphid experimentally reared on, 222.
ariotes, Chrysopa.
ariabazus, Microphanurus (see *M. aloysii-sabaudiae*).
asion, Heterospilus.
Aspergillus, attacking nymphs of *Schistocerca flavofasciatus* in Trinidad, 305.
ate, Meteorus.
Atelocera stictica, Scelionid parasite of, in Tanganyika, 142.
atis, Monolexis.
atricapillus, Chrysocoris.
augur, Urocervus.
aurantii, Toxoptera.
aurites, Taeniorhynchus (*Coquillettidia*).
auropunctata, Wasmannia.
 Australia, South, diapause in eggs of *Austroicetes cruciata* in, 1-17.
Austroicetes cruciata, diapause in eggs of, 1-17.

Avocado, food-plant of *Selenothrips rubrocinctus*, 313.
Axiagaster cambelli, Scelionid parasite of, in Solomon Is., 142.
Axonopus compressus (Savannah Grass), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.

B.

Badula insularis, new Coccid on, in Mauritius, 128.
badulae, Mimuspaspis.
 Banana, food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
Bandeiraea simplicifolia, Noctuid on, in Gold Coast, 59.
barrowi, Microphanurus.
Baryconus, erroneously recorded as a parasite of cacao thrips in Brazil, 314.
basalis, Microphanurus.
 Bean, Horse (see *Canavalia ensiformis*).
Beauveria globulifera, attacking cacao thrips, 313, 314, 317.
 Bed-bugs (see *Cimex*).
beneficians, Anagyrus.
Beta vulgaris, *Aphis fabae* reared on, 222.
biblis, Microphanurus.
bisselliella, Tineola.
 Blowflies, survey of, on sheep in British Is., 65-88, 95-111.
boleti, Scardia.
Bombyx, diapause in, 2, 16.
Borkhausenia pseudospretella, transferred to *Hofmannophila*, 208.
Borkhausenia stipella, larval characters of, 208.
Boxia khayae, gen. et sp. n., on *Khaya grandifoliola* in Gold Coast, 287-289.
Brachiaria mutica (Para Grass), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
bractella, Alabonia.
Brassica oleracea (see Cabbage).
brassicae, Pieris.
 Brazil, natural enemies of cacao thrips in, 314.
brevirostris, Acanthomia.
 British Isles, survey of sheep blowflies of, 65-88, 95-111; new brown Aphid from, 213.
brui, Thripoctenus.
brunneus, Lyctus.
buxtoni, Taeniorhynchus.

C.

- caballus*, *Aïdes* (*Ochlerotatus*).
 Cabbage (*Brassica oleracea*), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
 Cacao (*Theobroma cacao*), resistance of, to *Sahlbergella* in Gold Coast, 159-162; food-plant of *Schistocerca flavofasciata* in Trinidad, 294; natural enemies of *Selenothrips rubrocinctus* on, 313-321.
 Cacao Thrips (see *Selenothrips rubrocinctus*).
caesar, *Lucilia*.
Calandra spp., effect of, on stored wheat, 145-157.
californica, *Aclerda*.
Calliphora erythrocephala, infesting sheep in Britain, 65-86, 104.
Calliphora vomitoria, infesting sheep in Britain, 65 86, 104.
cambelli, *Axiagastus*.
Canavalia ensiformis (Horse Bean), *Schistocerca flavofasciata* fed on, in captivity, 292, 294; food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
cancellata, *Schistocerca*.
Cantheconidea robusta, Scelionid parasites of, in Ceylon, 142, 143.
caprealis, *Aglossa*.
Capriola (*Cynodon*) *dactylon* (Bahama Grass), not preferred food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
Capsella bursa-pastoris, new Aphid experimentally reared on, 222.
carinifrons, Cam., *Microphanurus*.
carinifrons, Fouts, *Microphanurus* (see *M. striaticeps*).
caryae, *Acrobasis*.
 Cashew, food-plant of *Selenothrips rubrocinctus*, 313.
cautella, *Ephesia*.
Celama sorghiella, larval characters of, 166, 172, 173.
cephalonica, *Corecya*.
Cephalosporium, attacking cacao thrips in Surinam, 313.
cerealella, *Sitotroga*.
 Ceylon, *Microphanurus* spp. in, 142, 143.
Chenopodium album, new Aphid experimentally reared on, 222.
Chortoicetes terminifera, diapause in, 15.
Chortophaga, diapause in, 15.
Chrysocoris atricapillus, Scelionid parasite of, in Java, 143.
Chrysopa spp., predacious on cacao thrips in San Thomé and Trinidad, 313, 314, 316, 317.
chrysopae, *Ooencyrtus*.
chrysosoma, *Taeniorhynchus* (*Coquillettidea*).
Cimex, toxicity of fumigants to, 19-26.
cinereus, *Anopheles*.
Circotettix, diapause in, 15, 16.
Cirsium arvensis, *Aphis fabae* reared on, 222.
citri, *Pseudococcus*.
 Citrus Aphid, Black (see *Toxoptera aurantii*).
 Citrus Mealybug (see *Pseudococcus citri*).
claveri, *Chrysopa*.
claviger, *Anopheles*.
 Clothes, fumigation of, against body lice, 19 26.
clytes, *Meteorus*.
Coccobacillus acridiorum, attacking *Schistocerca flavofasciata* in Trinidad, 306.
 Coconut (*Cocos nucifera*), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
 Coffee, *Pseudococcus kenyae* on, in Kenya, 131.
cognatella, *Aphis* (*Doralis*).
columbina, *Schistocerca*.
Conocephalus, diapause in, 1, 11.
Coquillettidia (see *Taeniorhynchus*).
Corecya cephalonica, larval characters of, 167, 183.
costalis, *Hypsopygia*.
constanti, *Anopheles*.
cristatula, *Nola*.
croce, *Meteorus*.
crolius, *Microphanurus*.
Crotophaga ani (Tick-bird), destroying *Schistocerca flavofasciata* in Trinidad, 304.
cruciata, *Austroicetes*.
Cryptoblabes gaudiella, larval characters of, 168, 187.
Culex andersoni subsp. *abyssinicus*, in Eritrea, 282.
Culex annulioris, in Eritrea, 281.
Culex decens, in Eritrea, 282; in Br. Somaliland, 328.
Culex duttoni, in Eritrea, 281; in Br. Somaliland, 327.
Culex ethiopicus, in Eritrea, 281; in Br. Somaliland, 327.
Culex fatigans, breeding places of, in Eritrea and Br. Somaliland, 282, 283, 327; a potential vector of yellow fever, 283.
Culex hortensis, breeding places of, in Syria, 246.

Culex laticinctus, breeding places of, in Syria, Eritrea and Br. Somaliland, 246, 282, 327.
Culex mimeticus, breeding places of, in Syria, 246.
Culex pipiens, in Eritrea, 282, 283 ; in Br. Somaliland, 327.
Culex pipiens molestus, in Syria, 246, 251.
Culex poecilipes, in Eritrea, 281.
Culex pygmaeus, in Eritrea, 282.
Culex salisburyensis, in Eritrea, 281.
Culex simpsoni, in Eritrea, 282.
Culex sinaiticus, breeding places of, in Eritrea and Br. Somaliland, 282, 327.
Culex sitiens, 281 ; breeding places of, in Br. Somaliland, 328.
Culex theileri, in Eritrea, 281 ; in Syria, 246.
Culex tigripes, breeding places of, in Eritrea and Br. Somaliland, 281, 327.
Culex trifilatus, in Eritrea, 282.
Culex tritaeniorhynchus, in Syria, 247 ; in Br. Somaliland, 327.
Culex univittatus, breeding places of, in Syria, Eritrea and Br. Somaliland, 247, 282, 327.
cumminsi, *Aedes* (*Aëdimorphus*).
Cynodon dactylon (see *Capriola*).

D.

dactyloctenii, *Trionymus*.
Dactyloctenium aegyptiacum, new Coccid on, in Mauritius, 124.
danaus, *Microphanurus*.
Dasycera, larval characters of, 205.
Dasycera sulphurella, larval characters of, 209.
Dasynus manihotis, Scelionid parasites of, in Java, 140, 143.
Dasyscapus parvipennis, parasite of cacao thrips in Gold Coast & Trinidad, 314, 317 ; introduction and establishment of, in other countries, 314-315.
Dasystoma, larval characters of, 203.
decens, *Culex*.
Dendrosoter, 258.
Dengue, potential vector of, in Eritrea, 283.
Depressaria, larval characters of, 203.
Derris Resin, effect of, on insect eggs, 225-244.
detritus, *Aedes*.
Diapause, in eggs of *Austroicetes cruciata*, 1-17.
differentialis, *Melanoplus*.

dimorpha, *Margaronia*.
Dinurothrips hookeri, *Dasyscapus parvipennis* experimentally parasitising, 315 ; thrips predacious on, in Trinidad, 316.
Dioscorea batatas (see Yam).
distingueundus, *Lariophagus*.
distorta, *Aclerda*.
ditella, *Tinea*.
Doclostaurus, diapause in, 15.
dominica, *Rhizopertha*.
Doralis (see *Aphis*).
Doryctes laemosacci, sp. n., parasite of *Laemosaccus* in Queensland, 257.
Doryctinae, characters of, 258.
d'thali, *Anopheles* (*Myzomyia*).
durbanensis, *Meteorus*.
duttoni, *Culex*.

E.

echinus, *Aedes*.
elutella, *Ephestia*.
Enarmonia nigricana, larval characters of, 170, 204.
Enarmonia pomonella, larval characters of, 170, 204.
enceladus, *Microphanurus*.
Endrosis lactella, in stored wheat, 152.
Endrosis sarcitrella, larval characters of, 171, 209.
Enicmus minutus, in stored wheat, 151.
Ephestia cautella, larval characters of, 168, 191, 193.
Ephestia elutella, larval characters of, 169, 191, 199.
Ephestia figulella, larval characters of, 194.
Ephestia sericarium (*kühniella*) larval characters of, 169, 191, 195 ; tests with plant insecticides against eggs of, 227-235.
Eriotremex, gen. n., for *Tremex smithi*, 42 ; scope and key to females of, 42-43.
Eriotremex malayanus, sp. n., from Malaya, 44.
Eritrea, mosquitos of, 279-285.
eritreae, *Aedes* (*Aëdimorphus*).
erythrocephala, *Calliphora*.
Ethiopian Region, *Microphanurus* spp. of, 135-144.
ethiopicus, *Culex*.
Etiella zinckenella, larval characters of, 166, 185.
Euchromius ocella, larval characters of, 166, 202.
Eucorystes aciculatus, 265.

Eucorystes remus, sp. n., bred from wood of *Mallotus philippinensis* in India, 263.

Eucorystes tenuis, sp. n., from India, 265.

euonymi, *Aphis*.

Euonymus (see Spindle).

Europe, studies on Siricids of, 27-51.

exempta, *Laphygma*.

exigua, *Laphygma*.

F.

fabae, *Aphis* (*Doralis*).

farinalis, *Pyralis*.

fatigans, *Culex*.

ferrugineus, *Laemophloeus*.

figulilella, *Ephestia*.

Finlaya (see *Aëdes*).

flavicornis, *Metzorius*.

flavofasciata, *Schistocerca*.

flavolineata, *Osmilia*.

floccosa, *Newsteadia*.

forficella, *Harpella*.

försteri, *Monolexis*.

Franklinothrips petulans, probably a synonym of *F. tenuicornis*, 315.

Franklinothrips tenuicornis, predacious on cacao thrips in Trinidad, 313-317.

Franklinothrips vespiiformis, predacious on cacao thrips in Trinidad and Brazil, 313-317.

Fumigation, against body lice, 19-26.

funestus, *Anopheles* (*Myzomyia*).

fusciventris, *Anagyrus*.

G.

Galeopsis speciosa, Aphid feeding on, 222.

Galleria mellonella, larval characters of, 166, 177.

gambiae, *Anopheles* (*Myzomyia*).

Gambusia affinis holbrooki, introduced into Eritrea against mosquitos, 285.

geniculatus, *Aedes*.

gibbicollis, *Xylopsocus*.

gigas, *Urocerus*.

gnidiella, *Cryptoblades*.

Gold Coast, new Braconids from, 59, 63; resistance of cacao to *Sahlbergella* in, 159-162; new Mirid on *Khaya* in, 287; Eulophid parasite of cacao thrips in, 314-315.

gossypiella, *Platyedra*.

granaria, *Calandra*.

granella, *Tinea*.

Grass, Bahama (see *Capriola dactylon*).

Grass, Corn (see *Manisuris exaltatus*).

Grass, Elephant (see *Pennisetum purpureum*).

Grass, Guatemala (see *Tripsacum laxum*).

Grass, Guinea (see *Panicum maximum*).

Grass, Para (see *Brachiaria mutica*).

Grass, Savannah (see *Axonopus compressus*).

gregaria, *Schistocerca*.

grisella, *Achroia*.

Guadeloupe, ant predacious on cacao thrips in, 313.

Guava, food-plant of *Selenothrips rubrocinctus*, 313.

gularis, *Aphomia*.

H.

haemorrhoidalis, *Heliothrips*.

Harpella forficella, 209.

Hecabolinae, characters of, 258.

Hecabolus, 258.

Hecabolus lycti (see *Monolexis*).

Hecabolus sulcatus, 258.

Heliothis obsoleta, Braconid parasite of, in Sudan, 61.

Heliothrips haemorrhoidalis, natural enemies of, in Trinidad, 314, 315.

Hercothrips insularis, natural enemies of, in Trinidad, 315, 316.

Heterospilus, 258.

Heterospilus asion, sp. n., parasite of Bostrychid in Queensland, 260.

Hibiscus rosa-sinensis, food-plant of *Schistocerca flavofasciata* in Trinidad, 294.

hirsutus, *Aedes* (*Aëdimorphus*).

Hofmannophila (*Borkhausenia*) *pseudospretella*, larval characters of, 170, 207.

hookeri, *Dimurothrips*.

Horismenus, parasite of Chrysopids in Trinidad, 316.

hortensis, *Culex*.

Houses, fumigation of, against body lice, 19-26.

Hydrogen Cyanide, fumigation with, against body lice, 19-26.

Hypsolophus, larval characters of, 203.

Hypsopygia costalis, larval characters of, 169, 198.

I.

illustris, *Lucilia*.

imperialis, *Sirex*.

India, Hymenopterous parasites in, **140, 141, 265.**
 Indo-Malayan Region, *Microphanurus* spp. of, **135-144.**
inquinata, *Sterrha*.
 Insecticides, of plant origin, ovicidal properties of, **225-244.**
insularis, *Hercotothrips*.
interpunctella, *Plodia*.
iona, *Chrysopa*.

J.

Java, *Microphanurus* spp. in, **140, 143.**
juglandis, *Acrobasis*.

K.

Kenya Colony, new Encyrtid parasite of *Pseudococcus kenyæ* established in, **129-133.**
kenyæ, *Pseudococcus*.
Khaya grandifoliola, new Mirid on, in Gold Coast, **290.**
khayæ, *Boxia*.
kivuisis, *Anagyrus*.
kleini, *Meteorus*.
komensis, *Meteorus*.
kühniella, *Ephestia* (see *E. sericarium*).

L.

lactella, *Endrosia*.
Laenophloeus spp., effect of, on stored wheat, **145-157.**
laemosacci, *Doryctes*.
Laemosaccus, new Braconid parasite of, in Queensland, **258.**
lal, *Meteorus*.
laodice, *Meteorus*.
Laphygma exempla, Braconid parasite of, in Transvaal, **61.**
Laphygma exigua, Braconid parasites of, in Africa, **57, 61.**
laphygmarum, *Meteorus*.
larides, *Microphanurus*.
Lariophagus distinguendus, effect of, on stored wheat, **145-157.**
Latania versaffeltii, new Coccid on, in Mauritius, **123.**
laticinctus, *Culex*.
 Lebanon, mosquitos of, **245-251.**
lemolea, *Spalgis*.
lemoleæ, *Telenomus* (*Microphanurus*).
Leucochrysa varia, predacious on cacao thrips in Trinidad, **314, 316.**
leverii, *Pseudococcus*.

Liadoxyela, **47.**
 Lice (see *Pediculus*).
 Light, effect of, on mosquitos, **89-93.**
 Light-traps, criticism of use of, for studying phototropism, **113-116.**
lilii, *Aedes* (*Stegomyia*) *simpsoni*.
Lindera tessellatella, larval characters of, **171, 210.**
lineaticollis, *Antestia*.
Liparis, diapause in, **2.**
lipsis, *Meteorus*.
Locusta, diapause in, **15**; colouration in, **306.**
Locusta migratoria, breeding of, in captivity, **256.**
Locustana, colouration in, **306.**
longiareolata, *Theobaldia* (*Allotheobaldia*).
longicornis, *Anagyrus*.
Loxostege, diapause in, **2, 16.**
Lucilia, diapause in, **2, 16.**
Lucilia ampullacea, **78.**
Lucilia caesar, infesting sheep in Britain, **65-86, 104.**
Lucilia illustris, infesting sheep in Britain, **65-86, 104.**
Lucilia sericata, infesting sheep in Britain, **65-86, 102, 110.**
luteocephalus, *Aedes* (*Stegomyia*).
Lutzia (see *Culex*).
lycti, *Monolexis* (*Hecabolus*).
Lyctus brunneus, on *Xanthophyllum* in Queensland, **261.**

M.

macmahoni, *Anopheles* (*Myzomyia*).
Macrosiphum solanifolii, **221.**
maculata (in error as *maculosa*), *Termitophylidea*.
maculipennis, *Plutella*.
mahensis, *Telenomus* (*Microphanurus*).
 Maize (*Zea mays*), food-plant of *Schistocerca flavofasciata* in Trinidad, **294.**
 Malaya, new Siricid from, **44**; new Braconid parasite of *Lyctid* from, **263**; *Microphanurus stoicus* in, **141.**
malayanus, *Eriotremex*.
Mallotus philippinensis, new Braconid bred from wood of, in India, **265.**
 Mango, food-plant of *Selenothrips rubrocinctus*, **313.**
manihotis, *Dasyneus*.
Manisuris exaltatus (Corn Grass), food-plant of *Schistocerca flavofasciata* in Trinidad, **294.**
Mansonioides (see *Taeniorhynchus*).
Margaronia dimorpha, Braconid parasite of, in Cape Province, **58.**

- margaroniae*, *Meteorus*.
mariae, *Aëdes* (*Ochlerotatus*).
maro, *Microphanurus*.
marquesanus, *Anagyrus*.
marteri, *Anopheles*.
mashonaensis, *Uranotaenia*.
mauritianae, *Neusteadia*.
 Mauritius, new Coccids from, 117-128.
Megapterites mirabilis, characters of, 46.
Melanoides tuberculata, in hot springs in Br. Somaliland, 324, 325.
Melanoplus spp., diapause in, 1, 2, 11, 15, 16.
mellonella, *Galleria*.
menecles, *Microphanurus*.
menopon, *Terale*.
Meteorus, revision of African spp. of, 53.
Meteorus ate, sp. n., from S.W. Africa, 62.
Meteorus clytes, sp. n., from Cape Province, 62.
Meteorus croce, sp. n., from Cape Province, 62.
Meteorus durbanensis, 63.
Meteorus flavicornis, 63.
Meteorus kleini, 63.
Meteorus komensis, morphology of, in Uganda, 60.
Meteorus lal, sp. n., from Cape Province, 57.
Meteorus laodice, sp. n., from S.W. Africa, 57.
Meteorus laphygmarum, morphology and hosts of, in Africa, 61.
Meteorus lipsis, sp. n., hosts of, in Africa, 59.
Meteorus margaroniae, morphology and host of, in S. Africa, 58.
Meteorus neavei, morphology of, in E. Africa, 58.
Meteorus nereus, sp. n., from Gold Coast, 63.
Meteorus testaceus, morphology and host of, in Cape Province, 56.
Meteorus tricolor, 63.
Meteorus trilineatus, morphology of, 56.
Meteorus triptus, sp. n., from S.W. Africa, 60.
Meteorus tydeus, sp. n., from Cape Province, 60.
mexicanus, *Melanoplus*.
Microphanurus, Ethiopian and Indo-Malayan spp. of, 135-144; key to species of, 136.
Microphanurus africanus, in Africa, 144.
Microphanurus aloysii-sabaudiae (*artabazus*), synonymy and hosts of, in Africa and Malaya, 141.
Microphanurus barrowi, parasite of Sphingid in India, 141.
Microphanurus basalis, parasite of *Nezara viridula* in Africa, 143.
Microphanurus biblis, sp. n., from Africa, 140.
Microphanurus carinifrons, Cam., in India, 140.
Microphanurus carinifrons, Fouts (see *M. striaticeps*).
Microphanurus crotius, in Uganda, 143.
Microphanurus danaus, in Africa, 142.
Microphanurus enceladus, in Africa, 140.
Microphanurus larides, sp. n., parasite of *Acrosternum prunasi* in Senegal, 141.
Microphanurus lemoleae (see *Telenomus*).
Microphanurus mahensis (see *Telenomus*).
Microphanurus maro, in Africa, 140.
Microphanurus menecles, in Africa, 140.
Microphanurus mopsus, in Africa, 139.
Microphanurus orontes, host of, in Africa, 142.
Microphanurus painei, parasite of *Axiagastus cambelli* in Solomon Is., 142.
Microphanurus priapus, parasite of Hemiptera in Java, 143.
Microphanurus seychellensis, parasite of Hemiptera in Seychelles, Africa and Ceylon, 143.
Microphanurus sipius, parasite of *Nezara viridula* in Kenya, 139.
Microphanurus stoicus, in Malaya, 141.
Microphanurus striaticeps, hosts of, in Africa and India, 139; *M. carinifrons*, Fouts nec Cam., a synonym of, 139.
Microphanurus sulmo, parasites of *Cantheconidea robusta* in Ceylon, 142.
Microphanurus suranus, parasite of *Antestia lineaticollis* in Uganda, 142.
Microphanurus trophoniui, host of, in Sumatra, 140.
Microphanurus vindicius, parasite of *Dasyneus manihotis* in Java, 140.
mimeticus, *Culex*.
Mimiaspis badulae, sp. n., on *Badula insularis* in Mauritius, 127.
Mimiaspis mimusopis, 128.
mimusopis, *Mimiaspis*.
minimus, *Anopheles*.
Minthea rugicollis, new parasite of, in Malaya, 263.
minutus, *Enicmus*; *Laemophloeus*.
mirabilis, *Megapterites*.
moestum, *Anacridium*.
molestus, *Culex pipiens*.
Monalocoropsis, 288.

Monolexis atis, sp. n., parasite of Lyctid in Queensland, 261.
Monolexis försteri, 262.
Monolexis (Hecabolus) lycti, 262.
Monolexis sorus, sp. n., parasite of Lyctid in Malaya, 262.
mopsus, *Microphanurus*.
 Mosquitos, of Eritrea, 279-285; of Br. Somaliland, 323-328; of Syria and Lebanon, 245-251; effect of temperature and light on breeding of, 89-93.
moubata, *Ornithodoros*.
Mucidus (see *Aedes*).
Musa (see *Banana*).
Muscina spp., infesting sheep in Britain, 72, 78, 85.
myersi, *Newsteadia*.
Myzomyia (see *Anopheles*).

N.

neavei, *Meteorus*.
Neoculex (see *Culex*).
nereus, *Meteorus*.
Newsteadia, key to species of, 120.
Newsteadia americana, 118, 120.
Newsteadia floccosa, 118.
Newsteadia mauritiana, sp. n., from Mauritius, 117.
Newsteadia myersi, 118.
Newsteadia tristani, 118.
Nezara viridula, Scelionid parasites of, in Africa, 139, 141, 143.
 Nicotine, effect of, on insect eggs, 225-244.
niger, *Urocetus*.
nigricana, *Enarmonia*.
nigricans, *Anagyrus*.
nigricornis, *Anagyrus* (see *A. fusciventris*).
nigriflagellum, *Anagyrus*.
Ninyas torvus, predacious on cacao thrips in Trinidad, 314, 316, 317.
Nola cristatula, larva figured, 172.
Nothris, larval characters of, 203.

O.

obsoleta, *Heliothis*.
ocellea, *Euchromius*.
Ochlerotatus (see *Aedes*).
Ooencyrtus chrysopae, parasite of Chrysopids in Trinidad, 316.
orbitalis, *Anagyrus*.
Ornithodoros moubata, pyrethrum-oil films against, 269-277.
orontes, *Microphanurus*.

Orphulella punctata, 306.
Oryza sativa (see *Rice*).
oryzae, *Calandra*.
Osmilia flavolineata, 306.

P.

pabulorum, *Muscina*.
painei, *Microphanurus*.
pallescens, *Schistocerca*.
pallescentella, *Tinea*.
pallidoconsersa, *Acrosternum*.
Panicum maximum (Guinea Grass), food-plant of *Schistocerca* spp. in Trinidad, 293, 294.
Papaver rhoeas, *Aphis fabae* reared on, 222.
Paracarnus sp., predacious on cacao thrips in Grenada and St. Lucia, 313.
Parallelia pudica, new Braconid parasite of, in Gold Coast, 59.
paranensis, *Schistocerca*.
parasitella, *Tinea*.
parvipennis, *Dasyscapus*.
Pediculus, toxicity of fumigants to, 19-26.
Pedrococcus simplex, sp. n., from Mauritius, 120.
pellionella, *Tinea*.
Pennisetum purpureum (Elephant Grass), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
petulans, *Frankliniethrips*.
pharoensis, *Anopheles*.
Phormia regina, infesting sheep in U.S.A., 111.
Phormia terraenovae, infesting sheep in Britain, 65-86, 104, 107, 108, 111.
 Phototropism, in insects, 113-116.
phragmitis, *Ripersia*.
Pieris brassicae, tests with plant insecticides against eggs of, 226-227.
pilosa, *Termitophylidea*.
pinguinalis, *Aglossa*.
pipiens, *Culex*.
Plaster Substrata, use of, for testing pyrethrum-oil films against ticks, 269-277.
Platyedra, diapause in, 16.
Platyedra gossypiella, experiments with light-traps for, 113.
Plodia interpunctella, larval characters of, 168, 185.
Plutella maculipennis, tests with plant insecticides against eggs of, 236-239.
poecilipes, *Culex*.
pomonella, *Enarmonia*.
portiludovici, *Pseudococcus*.
praesignata, *Schistocerca*.

pretoriensis, *Anopheles* (*Myzomyia*).
priapus, *Microphanurus*.
prunasis, *Acrosternum*.
Pseudococcus citri (*Citrus* Mealybug).
Wasmannia auropunctata associated with, in Trinidad, 317.
Pseudococcus kenyae, introduction and establishment in Kenya of new Encyrtid parasite of, 129-133.
Pseudococcus levari, 123.
Pseudococcus portiludovici, sp. n., on *Latania verschaffeltii* in Mauritius, 122.
pseudopretella, *Hofmannophila* (*Borkhausenia*).
Ptinus tectus, destroying dried insects, 78; in stored wheat, 151.
pudica, *Parallelia*.
punctata, *Orphulella*.
punctifrons, *Anagyrus*.
pygmaeus, *Culex*.
Pyrallis farinalis, larval characters of, 169, 197.
Pyrethrins, effect of, on insect eggs, 225-244.
Pyrethrum-oil Films, tests with, in plaster substrata against ticks, 269-277.
Pyroderces rileyi, larval characters of, 170, 204.

Q.

Queensland, new Braconid parasites of wood-boring beetles from, 257-262.
queenslandensis, *Aedes aegypti*.

R.

regina, *Phormia*.
remus, *Eucorystes*.
rhamni, *Aphis*.
Rhizopertha dominica, effect of, on stored wheat, 145-157.
rhodesiensis, *Anopheles* (*Myzomyia*).
Rice (*Oryza sativa*), food-plant of *Schistocerca flavofasciata* in Trinidad, 294.
richardii, *Taeniorhynchus* (*Coquillettia*).
rileyi, *Pyroderces*.
Rhipersia phragmitis, morphology of, 124.
robusta, *Cantheconidea*.
Rotenone, effect of, on insect eggs, 225-244.
rubrocinctus, *Selenothrips*.

rugicollis, *Minthea*.
Rumex spp., new Aphid experimentally reared on, 222.
russelli, *Thripoctenus*.

S.

sacchari, *Aclerda*.
Saccharum officinarum (see Sugar-cane).
sacharovi, *Anopheles*.
Sahlbergella spp., resistance of cacao to, in Gold Coast, 159-162; new genus allied to, in Gold Coast, 287.
salisburyensis, *Culex* (*Neoculex*).
sarcitrella, *Endrosia*.
Scardia boleti, larval characters of, 211.
scatophagoides, *Aedes* (*Mucidus*).
Schistocerca, diapause in, 15.
Schistocerca americana, 293.
Schistocerca cancellata, imaginal diapause in, 299.
Schistocerca columbina, *S. flavofasciata* recorded as, in Trinidad, 293.
Schistocerca flavofasciata, bionomics of, in Trinidad, 291-310.
Schistocerca gregaria, 291, 301; breeding of, in captivity, 254.
Schistocerca pallens, records of, in Trinidad, 293; comparison of, with *S. flavofasciata*, 298.
Schistocerca paranensis, breeding of, in captivity, 256; records of, in Trinidad, 292.
Schistocerca praesignata, nom. nud., *S. flavofasciata* recorded as, in Trinidad, 293.
Schistocerca simulatrix, 293.
Scotinophara, Scelionid parasite of, in Malaya, 141.
Selenothrips rubrocinctus (Cacao Thrips), natural enemies of, and their importance in control of, 313-321.
Senegal, new Scelionid from, 142.
sericarium, *Ephestia*.
sericata, *Lucilia*.
seychellensis, *Microphanurus*.
Seychelles, Scelionid parasite in, 143.
Sheep, survey of blowflies of, in Britain, 65-88, 95-111.
Siberia, new *Aedes* from, 311.
Sierra Leone, new Braconid from, 59.
Silvanus surinamensis, effect of, on stored wheat, 145-157.
simplex, *Pedrococcus*.
simpsoni, *Aedes* (*Stegomyia*); *Culex*.
simulatrix, *Schistocerca*.
sinaiticus, *Culex*.
singularis, *Sahlbergella*.
sipius, *Microphanurus*.

- Sirex*, key to females of European species of, **35**.
Sirex imperialis, **48**.
 Siricidae, studies of, **27-51**; key to genera of, **33**.
sitiens, *Culex*.
Sitotroga cerealella, larval characters of, **165-204**; tests with plant insecticides against eggs of, **235-236**.
smithi, *Eriotremex* (*Tremex*).
sociella, *Aphomia*.
solanifolia, *Macrosiphum*.
 Solomon Islands, Braconid parasite of Pentatomid in, **142**.
 Somaliland, British, mosquitos of, **323-328**.
sordens, *Apamea*.
sorghiella, *Celama*.
sorus, *Monolexis*.
Spalgis lemolea, Scelionid parasite of, in Uganda, **143**.
Spalhius, **258**.
spectrum, *Xeris*.
 Spindle (*Euonymus*), new brown Aphid on, in British Is., **213**.
Sporotrichum, probably infesting *Schistocerca flavofasciata* in Trinidad, **305**.
Stegomyia (see *Aedes*).
Sterryha inquinata, larval characters of, **166, 173**.
stictica, *Atlocera*.
stipella, *Borkhausenia*.
stoicus, *Microphanurus*.
 Stored Products, effect of insect infestation on, **145-157**; larvae of Lepidoptera associated with, **163-212**.
striaticeps, *Microphanurus*.
subnigricornis, *Anagyrus*.
subochrea, *Theobaldia*.
 Sudan, Hymenopterous parasites in, **61, 139**; introduction of *Gambusia* into Eritrea from, **285**.
 Sugar-cane (*Saccharum officinarum*), food-plant of *Schistocerca flavofasciata* in Trinidad, **294**.
sulcatus, *Hecabolus*.
sulmo, *Microphanurus*.
 Sulphur Dioxide, fumigation with, against body lice, **19-26**.
sulphurella, *Dasycera*.
 Sumatra, *Microphanurus trophonius* in, **140**.
superpictus, *Anopheles*.
suranus, *Microphanurus*.
 Surinam, fungus infesting cacao thrips in, **313**.
surinamensis, *Silvanus*.
 Syria, mosquitos of, **245-251**.
T.
tabaci, *Thrips*.
Taeniorhynchus aurites, in Eritrea, **280**.
Taeniorhynchus buxtoni, in Syria, **246**.
Taeniorhynchus chrysosoma, in Eritrea, **280**.
Taeniorhynchus richardii, in Syria, **245**.
Taeniorhynchus uniformis, in Eritrea, **280**.
taiganus, *Urocercus gigas*.
tapetzella, *Trichophaga*.
tectus, *Plinus*.
Telebolus, **258**.
Telenomus lemoleae, parasite of Lycac-nid in Uganda, **143**.
Telenomus mahensis, transferred from *Microphanurus*, **136**.
 Temperature, effect of, on mosquitos, **89-93**.
tenuicornis, *Franklinothrips*.
tenuis, *Eucorystes*.
Terate menopon, gen. et sp. n., from Ashanti, **265-266**.
Teratophylidea spp., predacious on cacao thrips in W. Indies, **314, 316, 317**.
terminifera, *Chortoicetes*.
terraenovae, *Phormia*.
tessellatella, *Lindera*.
testaceus, *Meteorus*.
theileri, *Culex*.
Theobaldia annulata, breeding places of, in Syria, **245**.
Theobaldia longiareolata, breeding places of, in Syria, Eritrea and Br. Somaliland, **245, 280, 328**.
Theobaldia subochrea, in Syria, **245**.
Theobroma (see Cacao).
theobroma, *Sahlbergella*.
Thripoctenus spp., parasitising thrips, **313**.
Thrips tabaci, *Dasyscapus parvipennis* experimentally parasitising, **315**.
Thysanolaena agrostis, new Coccid on, in Mauritius, **125**.
thysanolaenae, *Aclerda*.
 Tibet, new Siricids from, **39, 47, 48**.
tibetanus, *Urocercus gigas*.
 Tick-bird (see *Crotophaga ani*).
tigripes, *Culex* (*Lutzia*).
Tinea ditella, larval characters of, **171, 210-211**.
Tinea granella, larval characters of, **171, 210-211**.
Tinea pallescentella, larval characters of, **172, 210-211**.
Tinea parasitella, larval characters of, **210**.

Tinea pellionella, larval characters of, **172**.

Tineola bisselliella, larval characters of, **171, 210-211**.

torbus, *Ninyas*.

Toxoptera aurantii (Black Citrus Aphis), *Wasmannia auropunctata* associated with, in Trinidad, **317**.

Tremex, list of, **41**; key to European species of, **42**.

Trichlorethylene, fumigation with, against body lice, **19-26**.

Trichophaga tapetzella, larval characters of, **171**.

tricolor, *Meteorus*.

trifilatus, *Culex*.

trilineatus, *Meteorus*.

Trinidad, bionomics of *Schistocerca flavofasciata* in, **291-310**; natural enemies of cacao thrips and their importance in, **314-319**.

Trionymus dactyloctenii, sp. n., on *Dactyloctenium aegyptiacum* in Mauritius, **123**.

Triphleps spp., predacious on cacao thrips in Trinidad and San Thomé, **313**.

Tripsacum laxum (Guatemala Grass), not preferred food-plant of *Schistocerca flavofasciata*, **294**.

triptus, *Meteorus*.

tristani, *Newsteadia*.

tritaeiorhynchus, *Culex*.

trophoni, *Microphanurus*.

turkhudi, *Anopheles* (*Myzomyia*).

tydeus, *Meteorus*.

U.

Uganda, new Encyrtid parasite from, established in Kenya against *Pseudococcus kenya*, **129-133**.

Uncaria gambir, Hemipteron on, in Sumatra, **140**.

unguiculata, *Uranotaenia*.

uniformis, *Taeniorhynchus* (*Mansonioides*).

univittatus, *Culex*.

Uranotaenia mashonaensis, in Eritrea, **280**.

Uranotaenia unguiculata, breeding places of, in Syria, **245**.

Urocetus, key to females of European, **38**; Himalayan and Oriental species of, **47-48**.

Urocetus augur, subspecies of, **41**.

Urocetus gigas, new subspecies of, **40, 47**.

Urocetus niger, sp. n., from Tibet, **48**.
Ussuri, new *Aedes* from, **311**.

V.

Valanga, **296**.

varia, *Leucochrysa*.

variegata, *Antestia*.

versicolor, *Agonoscelis*.

vespiformis, *Franklinothrips*.

Viburnum opulus, new brown Aphid reared on, in British Is., **222**.

Vicia faba, *Aphis fabae* reared on, **222**.

vindicus, *Microphanurus*.

viridula, *Nezara*.

vittatus, *Aedes* (*Stegomyia*).

vomitaria, *Calliphora*.

W.

Wasmannia auropunctata, predacious on cacao thrips in Guadeloupe and Trinidad, **313, 314, 317**.

West Indies, natural enemies of cacao thrips in, **313, 314, 316**.

Wheat, Stored, effects of insect infestation on, **145-158**.

X.

Xanthophyllum mactinyrrii, Lyctid on, in Queensland, **261**.

xeraula, *Anchonoma*.

Xeris spectrum, distribution of, **38, 44**.

Xylopsocus gibbicollis, new Braconid parasite of, from Queensland, **260**.

Y.

Yam (*Dioscorea batatas*), food-plant of *Schistocerca flavofasciata* in Trinidad, **294**.

Yellow Fever, potential vectors of, in Eritrea, **283**.

Z.

Zea mays (see Maize).

zinckenella, *Etiella*.

ERRATA.

Vol. 33, page 178, line 5, for "siphonal index 2-15" read "siphonal index 12-15"

Vol. 34, page 129, line 18, for "*fuscipennis*" read "*fusciventris*"

„ „ 314, line 21, for "*Wesmannia*" read "*Wasmannia*"

„ pages 314, line 20, 316, 15 lines from end, 317, lines 19, 30, and page 319, last line, for "*maculosa*" read "*maculata*."

DATES OF PUBLICATION IN PARTS.

Part I pp. 1-88 ... 19 April 1943

Part II pp. 89-162 ... 5 July 1943

Part III pp. 163-244 ... 3 November 1943

Part IV pp. 245-328 ... 31 December 1943

INDEX TO NAMES OF PERSONS.

- Adamson, A. M., 291, 314, 320.
 Aitchison, J. E. T., 47.
 Allen, S., 269.
 Andrewartha, H. G., 1.
 Atteck, P. C., 320.

 Baker, R. E. D., 291.
 Banks, N., 316, 320.
 Bedford, H. W., 61.
 Bei-Bienko, G., 39.
 Benson, R. B., 27.
 Bland, R. H., 285.
 Box, H. E., 59, 161, 287, 290.
 Bradley, J. C., 27, 28.
 Brimblecombe, A. R., 258, 260, 261.
 Brooks, G., 261.
 Burca, B. de, 280-282, 285.
 Busvine, J. R., 19.
 Buxton, P. A., 26, 245, 246, 277.

 Callan, E. McC., 313.
 Cameron, A. E., 87.
 Carment, A. G., 39.
 Carpenter, G. D. H., 28.
 Carter, W. A., 157.
 China, W. E., 135, 287.
 Cockayne, E. A., 37.
 Compere, H., 129.
 Corbet, A. S., 163, 212.
 Cotterell, G. S., 59, 63.
 Crawford, J. C., 320.
 Cunningham van Someren, G. R., 323.

 de Burca, B., 280-282, 285.
 de Salvaza, R. V., 44.
 Doncaster, J. P., 239.
 Drake, C. J., 316, 320.
 Dudgeon, G. C., 48.

 Edelsten, H. M., 212.
 Edwards, W. H., 314.

 Forester, 57.
 Franchini, G., 280, 282.
 Freeman, J. A., 212.

 Gahan, A. B., 316, 320.
 Gardner, J. C. M., 265.

 Graham, W. M., 266.
 Greenslade, R. M., 212.
 Gurney, A. P., 291.
 Gussakovskii, V. V., 28, 37, 38.

 Haddow, A. J., 89.
 Hall, W. J., 117, 124.
 Hargreaves, E., 59.
 Hargreaves, H., 57.
 Harper, J. O., 89.
 Hinton, H. E., 163.
 Hobson, R. P., 87.
 Holborn, J. M., 203, 212.
 Howe, R. W., 145.

 Jacob, F. H., 221.
 Jefferson, G. T., 212.
 Johnston, H. B., 61.
 Jones, F. G. W., 224.
 Jones, M. G., 213.

 Kaulback, R. J. H., 39, 48.
 Kevan, D. K. McE., 291.

 Laing, F., 224.
 Lamborn, W. A., 142.
 Leeson, H. S., 245.
 Le Pelley, R. H., 130, 131.
 Lewis, D. J., 279.
 Liebermann, J., 291.

 MacDonald, 245.
 MacInnes, D. G., 323.
 MacLeod, J., 65, 95.
 Mamet, R., 117, 121.
 Mara, L., 280.
 Melville, A. R., 130, 131.
 Milne, A., 87.
 Milne, J., 37.
 Montshadsky, A. S., 311.
 More, J. A., 100.
 Muesebeck, C. F. W., 262.
 Murat, 253.

 Neave, S. A., 59.
 Nixon, G. E. J., 53, 135, 257.

 O'Farrell, A. F., 39.
 Ogloblin, A. A., 291.

Parr, H. C. M., 245.
Perrett, W. H., 37.
Piggott, M., 243.
Posnette, A. F., 159.
Potter, C., 225.

Raffaele, G., 282.
Rehn, J. A. G., 291.
Richards, O. W., 212.
Risbec, J., 142.
Robinson, G. G., 269.

Salvaza, R. V. de, 44.
Silva, P., 314.
Somerén, E. C. C. van, 324.
Somerén, G. R. C. van, 323.
Squire, F. A., 113.
Stackelberg, A. A., 311.
Stephen, A. C., 28.
Stickland, F. G., 157.
Stroyan, H. L. G., 212.

Tams, W. H. T., 163, 212.
Tattersfield, F., 225, 269, 277.
Theodor, O., 245.
Thomassett, H. P., 56.
Turner, R. E., 56-58, 60-63, 140.
Twigg, T. H., 323.

Uvarov, B. P., 291.

van Someren, E. C. C., 324.
van Someren, G. R. C., 323.
Vinson, J., 121.
Volkonsky, M. A., 253.
Volkonsky, M. T., 253.

Ward, F. K., 39, 47.
Waters, H. B., 161.

Zavattari, E., 280, 282.
Zeuner, F. E., 46.

